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CONTRACT TRIAL OF THE UNITED STATES COAST-LINE BATTLE SHIP *INDIANA*.

BY PASSED ASSISTANT ENGINEER HARRY HALL, U. S. NAVY.

The *Indiana* is a twin-screw armored coast-line battle ship, and was built by the William Cramp & Sons' Ship and Engine Building Company, of Philadelphia, Pa., the designs having been furnished by the Navy Department. The contract was signed on November 19, 1890, the price being $3,063,333, and the time for completion three years. The speed guarantee was fifteen knots per hour, to be maintained successfully for four consecutive hours, during which period the air pressure in the fire rooms was not to exceed one inch of water, the vessel to be weighted to a mean draught of twenty-four feet. It was stipulated that for every quarter knot of speed maintained above fifteen knots the contractors should receive a premium, over and above the contract price of the vessel, of twenty-five thousand dollars, and that for every quarter knot the vessel failed to reach the guaran-

teed speed there should be deducted from the contract price the sum of twenty-five thousand dollars.

HULL.

The hull is constructed of mild steel of domestic manufacture, with frames spaced 4 feet throughout the length of the double bottom, and 3.5 feet forward and abaft the double bottom. The thickness of the outer keel plate is $\frac{3}{4}$ inch, of the inner $\frac{5}{8}$ inch, and of the vertical keel $\frac{1}{2}$ inch. The outer bottom plating is $\frac{5}{8}$ inch thick, and the inner bottom plating $\frac{3}{8}$ inch.

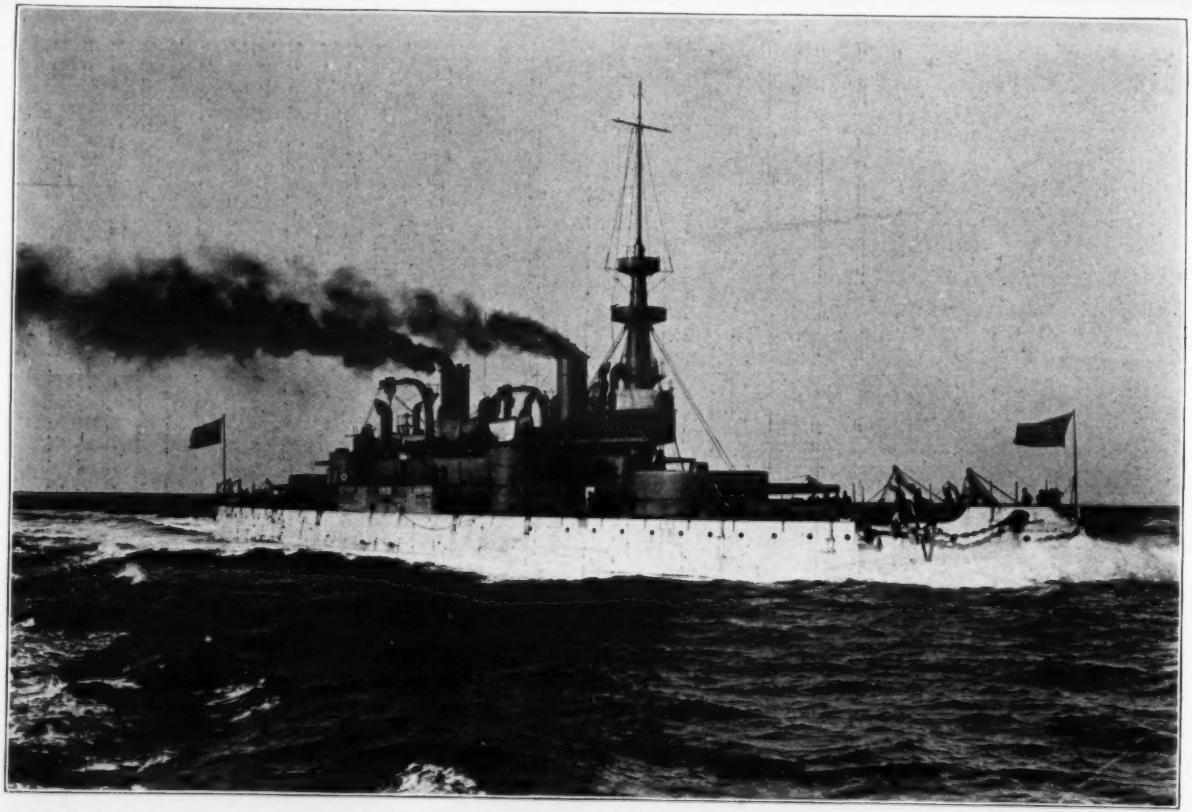
The ship is divided into 269 water tight compartments. The double bottom extends from frame 18 to frame 78, a distance of 240 feet, and runs up to the armor shelf. It is 3 feet 3 inches in depth amidships and is divided into 19 water tight compartments. Coffer dams, 6 feet wide, are on each side of the vessel extending forward and abaft the armor belt, from the orlop deck to the berth deck, and are packed with cellulose. The transverse bulkheads are carried through the coffer dams to divide them into water tight compartments.

Hold.—In the hold abaft the engine compartments and forward of the boiler compartments are: Coal bunkers, 6-inch and 8-inch magazines and shell rooms, fixed ammunition rooms, turning gear for 13-inch turrets, store rooms and trimming tanks.

After platform.—On the after platform are: 13-inch magazines and shell rooms, 13-inch handling room, store rooms, steering engine and gear.

Forward platform.—On the forward platform are: 13-inch magazines and shell rooms, 13-inch handling room, store rooms.

Orlop deck.—On the orlop deck, forward and abaft the athwartship armor, are: Store rooms and fresh water tanks; and within the citadel, coal bunkers, ventilating fans, dynamo room, hydraulic machinery, 8-inch turret turning machinery, air compressors for torpedo tubes, central station for voice pipes and telephones, auxiliary magazines for 8-inch, 6-inch and rapid fire guns. Outboard on each side is an armored passage extending from bulkhead at frame 29 to bulkhead at frame 64. Inboard of the armored passage, and extending the same length, is an ammunition passage.



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U. S. S. "INDIANA."

Berth deck.—On the berth deck are the living quarters, the auxiliary boilers, coal bunkers, the refrigerating plant and torpedo rooms.

There are 30 coal bunkers with a total capacity of 1,650 tons at 43 cubic feet to the ton. They are distributed as follows: 16 in the hold with a capacity of 1,340 tons; 6 on the orlop deck with a capacity of 78 tons; 8 on the berth deck with a capacity of 232 tons. They are filled through chutes and trunks fitted between decks. The trunks are fitted with shunt doors at the top where they pass through the coal bunkers on the berth deck, and vertical doors at the bottom, so that the coal can be passed from these bunkers into the trunks, and through the orlop deck into the bunkers below. Armored shutters are fitted in the trunks where they supply coal to the bunkers through the orlop deck.

There are two ash chutes on each side, on the outside of the vessel, semi-oval in shape. The upper ends of the chutes extend above the main deck, where hoppers are formed inside. Trolley-ways for carrying the ash buckets are fitted under the deck beams above, leading from the ash hoists to the chutes.

Drainage system.—For draining the compartments there is a 14-inch main drain pipe on the port side and a $7\frac{1}{2}$-inch secondary drain pipe on the starboard side, extending in the double bottom throughout the engine and boiler compartments. Each pipe has branches leading to a cistern in each compartment and is fitted with screw-down non-return valves. The main drain pipe is connected with the port main circulating pump, and through the manifolds with four engine room auxiliary pumps. The secondary drain pipe is connected through the manifolds with the suctions of eight of the auxiliary pumps. The auxiliary feed pumps are connected with the bilge of the boiler compartments, and the fire and bilge pumps with the bilge of the engine compartments, and also with the bilge of the compartment next abaft the engine rooms. The side compartments empty directly into the midship compartments by means of water-tight sluices on the bulkheads. The compartments at the extremities drain into the compartments at the ends of the main drain pipe by means of gun-metal

sluices. Each compartment within the double bottom has its own suction, and these suctions lead to valve boxes placed in the engine rooms. The suctions forward and abaft the limits of the double bottom are led to valve boxes located in the fire rooms and engine rooms respectively. A drain valve is fitted to each compartment above the platform decks, with a strainer box over it, and with a pipe leading to the bilge. For draining above the orlop deck, forward and aft, screw-down valves are fitted in the armor deck, two forward and two aft, with sluice valves in the store room and other bulkheads; from these valves pipes lead the water to the main drain pipe. The waste water from the bath and wash rooms is led by pipes to tanks located in the ammunition passages, and is pumped overboard by a Blake plunger pump, with steam cylinder $4\frac{1}{2}$ inches diameter, plunger $3\frac{3}{4}$ inches diameter, and stroke 7 inches.

The boats carried are as follows:

1 33-foot steam cutter.
1 30-foot steam cutter.
2 29-foot whale boats.
1 30-foot whale boat gig.
1 32-foot sailing launch.
2 28-foot cutters.
1 26-foot cutter.
1 24-foot cutter.
2 20-foot dinghies.
1 Balsa.
2 Punts.

Length between perpendiculars, feet	348.
on L.W.L., feet	348.
over all (including rudder), feet and inches	350–10½
Beam, extreme, feet and inches	69– 3
at L.W.L., feet and inches	69– 3
Ratio of length to beam	5.03
Depth in hold from top of main deck beams to top of floor, feet	32
Height of superstructure above main deck beams, feet and inches	7– 4
Draught forward, seagoing trim, feet	23.69
aft, seagoing trim, feet	24.06
mean, seagoing trim, feet	23.88

Displacement, seagoing trim (load draught), tons	10,225.
per inch, at L.W.L., tons	42.76
Area of immersed midship section, square feet	1,540.
L.W.L. plane, square feet	17,980.
Center of gravity of L.W.L. plane, aft of midship section (frame No. 45), ft.	.94
buoyancy above bottom of keel, feet	13.52
aft of midship section, feet	1.86
gravity above bottom of keel, feet	24.
Transverse metacenter above center of buoyancy, feet	15.27
Longitudinal metacenter above center of buoyancy, feet	335.5
Coefficient of fineness on extreme dimensions	.622
of midship section	.931
of L.W.L	.746
Cylindrical coefficient	.668
Number of frames	91.
water tight compartments	269.

ARMOR.

The armor consists of a side belt of Harveyized nickel steel extending through the machinery and boiler spaces and to the bases of the 13-inch gun turrets. It is 3 feet above, and 4 feet 6 inches below the normal load water line amidships, diminishing to 4 feet 2½ inches below the load water line at the ends. The outside surface conforms to the shape of the vessel, with a thickness of 18 inches extending from the top of armor to 12 inches below the load water line, from which point it tapers to 8 inches in thickness at top of armor shelf. At each end of the side, or water line belt, there is an athwartship belt 14 inches thick, thus completing the fort or armored citadel. The citadel is covered with an armored deck of nickel steel 2¾ inches thick, and forward and abaft the citadel there are protective decks of 3-inch nickel steel. Above the 18-inch side belt, extending to the main deck, there is a casemate of 5-inch armor, made up of two ½-inch plates and one 4-inch plate.

The armor of the turrets for the 13-inch guns is of nickel steel 17 inches thick, and the bases of the turrets are protected by barbettes of the same thickness of nickel steel. The armor of the turrets of the 8-inch guns is 6 inches thick, the top plating 2 inches, and the sighting towers 5 and 3 inches thick. The bases of the 8-inch turrets are protected by barbettes with armor 8

inches thick on the outer sides and 6 inches thick on the inboard sides.

The armored protection of the 6-inch guns is 5 inches thick, made up of two inner thicknesses of ½ inch each and an outer thickness of 4 inches. The armored protection for the 6-pounder guns on the main deck is 2 inches thick. The armored protection for the 1-pounders at the ends of the vessel consists in having the plating increased to a total thickness of 2 inches in wake of the ports, so that it will act as a shield.

The conning tower is located above the superstructure deck; it is of steel, forged hollow in one piece, 10 inches thick, and has an internal diameter of 6 feet 11 inches.

An armored tube, 7 inches thick and 12 inches internal diameter, extends from the conning tower to the armored deck and protects the electric wires, voice tubes, connections to engine room telegraphs, steering gear and engine tell-tales.

ARMAMENT.

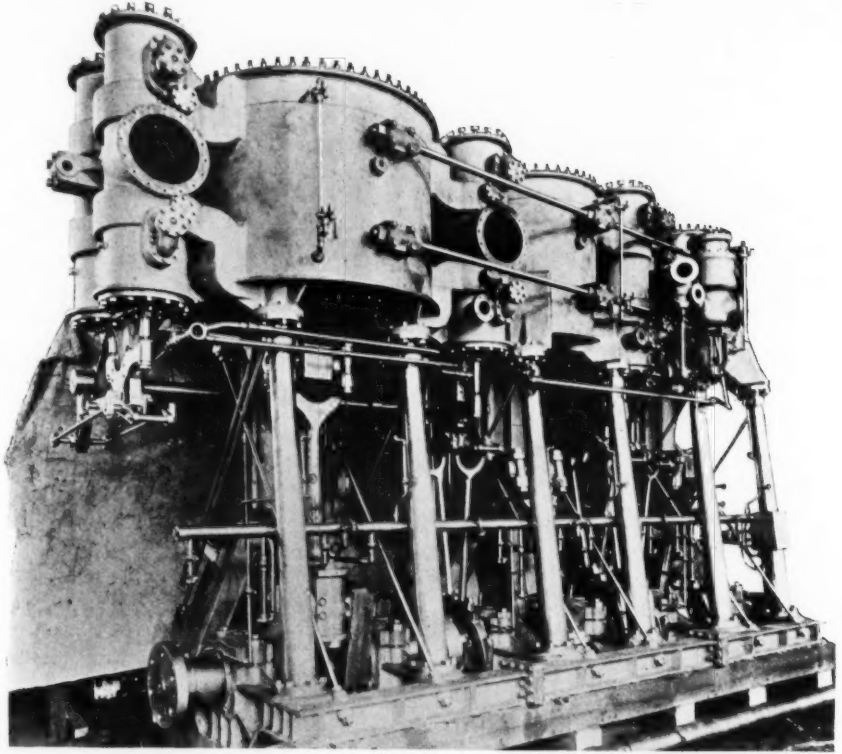
The main battery consists of four 13-inch breech loading rifles, 35 calibers, mounted in pairs in the two main turrets; eight 8-inch breech loading rifles, 35 calibers, mounted in pairs in the four turrets on the superstructure; and four 6-inch breech loading rifles, two on each side, on the main deck within the superstructure.

The secondary battery consists of twenty 6-pounder Hotchkiss rapid fire guns; six 1-pounder Hotchkiss rapid fire guns; and four light machine guns in the military tops.

The 13-inch turrets are worked by steam, and the guns by hydraulic power; the 8-inch turrets by steam power, and the guns by hand. The 6 inch guns are worked by hand on central pivot carriages.

There are six tubes for Whitehead torpedoes, two on each side, one in the bow, and one in the stern, all discharging directly from the berth deck.

The armament is a heavy one, throwing a weight of projectile from the main battery, in boadside at one discharge, of 5,600



TRIPLE-EXPANSION ENGINE U. S. S. "INDIANA."

pounds; and at one complete discharge of the main battery, of 6,800 pounds.

MAIN ENGINES.

There are two vertical inverted, direct acting, triple expansion engines placed abreast of each other in separate water tight compartments, the high pressure cylinders being forward.

Each cylinder is supported by an inverted Y frame on one side, and by two hollow forged steel cylindrical columns on the other. The intermediate and low pressure cylinders are steam jacketed on the sides and bottom, but the high pressure are not, but are fitted with working liners. There are no starting valves on the cylinders, provision being made for starting the engines by admitting live steam to the receivers. The relief valves for the cylinders are placed on the valve chest casings, on connections between the steam and exhaust sides of the main valves. There are two receivers for each engine, consisting of exhaust pipes and valve chests, the safety valves of which are set at 100 pounds for the I.P. and at 60 pounds for the L.P. The main valves are of the single ported piston type, there being for each engine, one for the H.P., two for the I.P. and four for the L.P. cylinder. They are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. The valve gear is of the Stephenson type with double bar links. There are no independent cut-off valves, but provision is made to cut off in each cylinder, varying from .5 to .7 of the stroke, by means of a block to which the suspension links are attached, which block can be moved by hand screw gear in a slot in the end of the arm on the reversing shaft.

The main pistons are steel castings, dished, and are each fitted with two packing rings $\frac{5}{8}$ inch wide and $\frac{3}{4}$ inch thick. The piston rods and connecting rods are of forged steel. The crossheads are of forged steel, and each has a manganese bronze slipper, the sliding faces of which are fitted with white metal. The crosshead guide to take the thrust when going ahead is of cast iron bolted to the inverted Y frame. The back of the guide is recessed and covered with wrought-iron plates to form a

passage for circulation of water. Cast-iron lips are bolted on each side of the go-ahead guide to take the thrust when backing. The eccentrics are of cast iron. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing one by through bolts in slotted holes. The eccentric straps are of composition, faced with white metal, and the eccentric rods of forged steel. The I.P. and L.P. valve stems have manganese bronze crossheads which take hold of the link blocks directly. Each engine bed plate consists of three sections of steel castings. The steam reversing gear consists of a cylinder 14 inches in diameter and 20 inches stroke, secured to an engine Y frame, the piston rod being connected to an arm on the reversing shaft. The valve is moved by a hand lever and is controlled by a floating lever. The hand reversing gear consists of a wheel, worm shaft, pinion and rack, the latter being connected to an arm on the reversing shaft.

There is a double cylinder, simple, inverted, turning engine with cylinders 7 inches in diameter and 7 inches stroke secured to the high pressure Y frame. It drives a worm wheel on the forward end of the high pressure crank shaft by means of worm gearing and a second worm; the latter is made to slide on a feather key, and is held in place by a collar below and a removable key above it. A ratchet is fitted to the shaft of the engine for turning by hand.

Each main engine is fitted with a disc stop valve 13¼ inches in diameter, having a screw stem and a balance piston, and a butterfly throttle 15⅛ inches in diameter. The main steam pipes are of copper and strengthened with steel bands 6 inches apart.

In the port engine room there is a distributing oil tank supplied from the main oil tanks by a Blake duplex pump, steam cylinders 2 inches in diameter, oil cylinders 1¼ inches in diameter, stroke 2¾ inches. The tank is fitted with an overflow pipe. Distributing pipes lead to the various manifolds which are fitted with adjusting valves, and from the manifolds tubes lead to the various parts to be lubricated. The suction pipe of the pump is fitted with a strainer.

Cylinders, number for each engine			3
diameter of H.P., inches			34 7/16
diameter of I.P., inches	Starboard		48 1/2
	Port		48
diameter of L.P., inches			75
Stroke of pistons, inches			42
Valves, diameter of H.P. (one for each cylinder), inches			17
diameter of I.P. (two for each cylinder), inches			17
diameter of L.P. (four for each cylinder), inches			17
Balance pistons, diameter of H.P., inches			5 1/2
diameter of I.P., inches			5 1/2
diameter of L.P., inches			7
Valve stems, H.P. (1) diameter, inches			2 5/8
H.P. (1) diameter through valve, inches			1 3/4
I.P. (2) diameter, inches			2 5/8
I.P. (2) diameter through valve, inches			1 3/4
L.P. (4) diameter, inches			2 3/8
L.P. (4) diameter through valve, inches			1 3/4
Main steam pipe (13 inches diameter) area of cross section, square inches			132.73
Exhaust pipe to I.P. cylinder (16½ inches diameter) area of cross section, square inches			213.82
to L.P. cylinder (20½ inches diameter) area of cross section, square inches			330.06
to condenser (2) (18½ inches diameter) area of combined cross sections, square inches			537.6
Volume swept by H.P. piston per stroke, cubic feet			22.17
I.P. piston, per stroke	Starboard, cubic feet		43.69
	Port, cubic feet		43.51
L.P. piston, per stroke, cubic feet			106.91
Ratio of net area of H.P. to I.P. pistons			1.97
I.P. to L.P. pistons			2.45
H.P. to L.P. pistons			4.82
Clearance of H.P. cylinder, per cent	Starboard	Top	14 76
		Bottom	24.33
	Port	Top	14.76
		Bottom	24.33
Clearance of I.P. cylinder, per cent	Starboard	Top	12 03
		Bottom	22.88
	Port	Top	12.10
		Bottom	22.05
Clearance of L.P. cylinder, per cent	Starboard	Top	9 09
		Bottom	19.59
	Port	Top	9.09
		Bottom	19.28
Piston rods, diameter, inches			7
length from piston to crosshead, feet and inches			5-5 5/8

Connecting rods, length from center to center, feet	7
diameter of upper end, inches	6⅝
diameter of lower end, inches	8½
thickness (sides as faced), inches	6⅝
crosshead bolts (4), diameter, inches	3
crank pin bolts (2), diameter, inches	4¼
Crossheads, surface (ahead), square inches	446½
surface (backing), square inches	352½
pins, diameter, inches	7½
pins, length, inches	9⅛
Reversing gear, steam cylinder, diameter, inches	14
stroke, inches	20

Shafting and Bearings.—The crank, line and propeller shafting is hollow and of forged steel. The crank shaft of each engine is in three interchangeable sections, the cranks placed at angles of 120 degrees, and for the ahead motion follow in the order H.P., I.P. and L P. There are two sections of line shafting to each engine supported on three bearings. The propeller shafts are fitted with a composition casing from inboard the stern tube stuffing box to the propellers; they extend far enough inboard to allow the inboard stern bearings to be withdrawn without moving the shafts. The shaft coupling bolts are tapered and finished to fit the holes snugly. They are put in from the after side of the coupling and are set up on the forward side with a wrought-iron nut and split pin.

Each thrust bearing is of cast iron of the horse shoe pattern. The end and side walls of the pedestal form an oil trough inside of which, both forward and aft the horse shoes, is a composition bearing lined with white metal for taking the weight of the shaft. The cap of this bearing is of cast iron lined with white metal. There is an oil cup in the top of each horse shoe, from which there is an oil hole to each collar, the white metal being channeled for the distribution of the oil. At each end of the bearing there is a divided stuffing box and gland to prevent the escape of oil. The pedestal is bolted to a cast iron sole plate fitted with wrought-iron wedges at each end of the pedestal for adjusting the bearing fore and aft.

Crank shafts, diameter, inches	14
axial hole, inches	6
coupling discs, diameter, inches	26½
coupling discs, thickness, inches	3½
tapered coupling bolts in one flange (6), diameter, inches	3⅛ to 3 1/16
journals, diameter, inches	14
journals, length, inches	17⅜
length of each section, feet and inches	8–6
Crank pins, diameter, inches	15
length, inches	17
axial hole, inches	6½
Crank webs, width, inches	15½
thickness, inches	9½
Thrust shafts, diameter, inches	13¾
diameter of coupling disc, inches	26½
axial hole, inches	6
collars, number each shaft	11
collars, diameter, inches	21
collars, thickness, inches	2
collars, distance between, inches	4
surface, total for both engines, square inches	4,353.18
length, feet and inches	16–7/8
Line shafts, diameter, inches	13¾
axial hole, inches	6
diameter of coupling discs, inches	26½
(2) total length, feet	40
Propeller shafts, diameter, inches	14
axial hole, inches	6
diameter of coupling discs, inches	26½
length, feet and inches	40–8
Stern bracket bearing, length, inches	49⅛
diameter, inches	15 7/16
Stern tube bearing, length... forward, inches	33½
Stern tube bearing, length... aft, inches	35½

There are six coupling bolts for each section of shafting. They are taper, from $3\frac{1}{8}$ to $3\frac{1}{16}$ inches in diameter.

Main Condensers.—There are two main condensers, one for each engine, of cast composition, in five sections, including the heads, and bolted together. The circulating water passes through the tubes. Baffle plates are fitted to direct the steam over the tubes, and plates are provided for supporting the tubes and also to act as baffle plates.

Diameter of shell (inside), feet and inches	5–9
Thickness of shell, inch	$\frac{1}{2}$
Length over heads, feet	12
Tubes, diameter (outside), inch	$\frac{5}{8}$
length between heads, feet and inches	10–3
thickness, No. 20 B.W.G., inch	.035
number in each condenser	3,790
Cooling surface, each condenser, square feet	6,355
total, square feet	12,710
Ratio of total cooling to total heating surface.. Main boilers	1 to 1.356
Main and auxiliary boilers.	1 to 1 51

Main Air Pumps.—For each main engine there is a Blake double, vertical, single acting air pump, similar to those on the *Minneapolis*. The steam cylinders are placed directly over the pump cylinders, the pump rods and piston rods forming a continuous length. The pumps are connected by means of a beam, which is pivoted at its center, and from which beam the valve motion is actuated. The beam receives its motion through links swinging from crossheads on the pump and piston rods.

Diameter of steam cylinders (2), inches	12
pump cylinders (2), inches	25
Stroke, inches	18
Diameter of piston rods, inches	$2\frac{1}{4}$
pump rods, inches	4
Kind and diameter of pump valves (vulcanized rubber), inches	$5\frac{1}{2}$
Ratio of volume swept by L.P. piston, per stroke, to that of the two air pump buckets, per stroke	10.59

Main Circulating Pumps.—For each main condenser there is a centrifugal double inlet circulating pump, which is arranged to draw from the sea, bilge and main drain pipe, and to discharge either into the condenser or directly overboard. It is driven by a horizontal single cylinder engine. Each pump is capable of discharging 9,000 gallons of water per minute from the bilge. The sea and bilge injection valves are fitted with a self-locking arrangement so that both cannot be opened at the same time.

Diameter of steam cylinder, inches	12
Stroke, inches	6
Diameter of pump runner, inches	32

Width of runner, inches.....at hub $6\frac{3}{4}$, at rim	$2\frac{3}{4}$
Diameter of inlet nozzle, inches	15
outlet nozzle, inches	15

Auxiliary Condensers.—There is in each engine room a Wheeler condenser connected with the auxiliary exhaust pipes. Each has a horizontal combined air and circulating pump, the steam cylinder being between the water cylinders, and all the pistons being on one rod. The tubes are arranged and packed as in the main condensers.

Cooling surface, one condenser, square feet	400
Diameter of steam cylinder, inches	8
water cylinder (circulating), inches	9
air pump cylinder, inches	9
Stroke, common, inches	10

Screw Propellers.—The propellers are of manganese bronze, each with three adjustable blades bent back $15\frac{1}{2}$ degrees. They are true screws, with the pitch variable from 14 feet 3 inches to 16 feet 3 inches. Each boss is secured to the shaft by a feather key and a wrought steel nut screwed on and locked in place. The end of the hub is covered with a composition cap.

Number of blades	3
Diameter, feet and inches	15-6
of hub, feet and inches	$3\text{-}11\frac{1}{2}$
Length of hub, feet and inches	3-1
Pitch as set, feet	16
Greatest width of blade (4 feet from axis), inches	$45\frac{3}{16}$
Helicoidal area of each screw, square feet	53.859
Projected area, square feet	45.24
Disc area, square feet	188.69
Pitch ÷ diameter	1.03
Helicoidal area ÷ disc area	.285
Projected area ÷ disc area	.24
Disc area of both screws ÷ I.M.S	.245
Immersion of center at mean draught (23.88 feet), feet	15.88
Center above lowest point of keel, feet	8
from center line of vessel, feet and inches	11-10

BOILERS.

There are four double ended main and two single ended auxiliary steel boilers of the horizontal fire tube type. Each main boiler has eight, and each auxiliary boiler two corrugated furnaces. The shell of each main boiler is made up of three courses of three plates each. The longitudinal joints of the shells of the main boilers are treble riveted with double butt straps, and the circumferential joints are lapped and treble riveted. The shell of each auxiliary boiler is in one course of two plates, double butt strapped and treble riveted, the joints with the heads lapped and double riveted. The joints in furnaces and combustion chambers are single riveted. The heads of the main boilers are flat; those of the auxiliaries are curved at the top to a radius of 2 feet $2\frac{1}{2}$ inches for the front head, and 2 feet $1\frac{39}{64}$ inches for the back head. The furnaces are fitted with "Cone's" patent shaking grate bars. Each main boiler has one quadruple $3\frac{1}{2}$-inch safety valve in one case, and each auxiliary boiler one 3-inch double safety valve in one case. Weir's hydrokineters are fitted to each main boiler for circulating the water while raising steam if there is steam in one boiler. The auxiliary feed pumps can be used to circulate the water, pumping from the bottom blow and delivering through the auxiliary feed checks, the main and auxiliary internal feed pipes being connected and arranged to give a good distribution of the water. The tubes in all boilers are of steel.

The main boilers are located fore and aft in four water-tight compartments. There is a passage way amidships extending from the athwartship engine room bulkhead to the athwartship bulkhead of the forward fire rooms, and in this passage way there are water tight doors to each fire room. By this arrangement there are two athwartship fire rooms in each main boiler compartment, and eight main fire rooms in all. The auxiliary boilers are located on the berth deck in separate boiler rooms. There are two main and two auxiliary smoke pipes, the latter running up inside the former.

MAIN BOILERS.

Steam pressure, pounds	160
Number of boilers	4

Length, feet	18
Diameter, outside, feet	15
Thickness of shell, inches	1 19/64
heads, top, inch	1
bottom, inch	3/4
tube sheets, inch	5/8
furnaces, inch	1/2
Combustion chambers, number in each boiler	4
thickness of plates, inch	9/16
width at top, feet and inches	2-5 5/8
depth, feet and inches	7-5 1/2
Furnaces, greatest internal diameter, feet and inches	3-4
least internal diameter, feet	3
length of grate, feet and inches	5-9
number in each boiler (corrugated)	8
Tubes, outside diameter, inches	2 1/2
length between tube sheets, feet and inches	6- 8/8
number of ordinary	676
number of stay	248
spaced vertically, inches	3 1/2
horizontally, inches	3 3/4
thickness of ordinary, B.W.G. No. 12, inch	.109
stay, B.W.G. No. 6, inches	.203
Diameter of rivets in shell sheets, inches	1 1/4
screw stays, inches	1 1/16
Number and diameter of through upper braces, inches	24 of 2 1/4, 3 of 2 1/2
lower braces, inches	3 of 1 3/4
braces around lower manholes, inches	12 of 1 1/4
from head to back tube sheets, inches,	20 of 2
Heating surface, tube, square feet	3,647.5
furnace, square feet	245
combustion chambers, square feet	418
total, square feet	4,310.5
Grate surface, square feet	138
Area through tubes, square feet	25.13
over bridge walls, square feet	15.56
Volume of furnaces and combustion chambers above grates, cubic feet,	559.93
Steam room, water six inches above tubes, cubic feet	737.41
Water surface, water six inches above tubes, square feet	239.22
Smoke pipes (2), diameter, feet	7
area of both, square feet	68.42
height above lowest grates, feet	70
Number and diameter of safety valves (four on one base), inches	4 of 3 1/2
Diameter of boiler main stop valves, inches	9
auxiliary stop valves, inches	5

Totals for four boilers:	
Heating surface, tube, square feet	14 590
furnaces, square feet	980
combustion chambers, square feet	1,672
total, square feet	17,242
Grate surface, square feet	552
Area through tubes, square feet	100.52
over bridge walls, square feet	62.24
Volume of furnaces and combustion chambers above grates, cu. ft	2,239.72
steam room, cubic feet	2,949.64
Area of water surface, square feet	956 88
Ratios:	
Tube H.S. to G.S	26.43 to 1
Furnace H.S. to G.S	1.78 to 1
Combustion chamber H.S. to G.S	3.01 to 1
Total H.S. to G.S	31.24 to 1
Area through tubes to G.S	.18 to 1
Steam room per square foot of G.S	5.34 to 1
Volume of furnaces and combustion chambers above grates to G.S	4 06 to 1

AUXILIARY BOILERS.

Steam pressure, pounds	160
Number of boilers	2
Length, feet and inches	8–6
Diameter, outside, feet and inches	10–1 $\frac{55}{32}$
Thickness of shell, inch	$\frac{57}{64}$
Thickness of heads, top, inch	$\frac{57}{64}$
bottom, inch	$\frac{3}{4}$
Thickness of tube sheets, inch	$\frac{3}{4}$
Thickness of furnaces, inch	$\frac{15}{32}$
Combustion chambers, number in each boiler	2
thickness of plates, inch	$\frac{1}{2}$
width at top, inches	23$\frac{1}{4}$
depth, feet	4
Furnaces, greatest internal diameter, feet and inches	3– $\frac{1}{16}$
least internal diameter, feet and inches	2–9
length of grate, feet	6
number in each boiler, corrugated	2
Tubes, outside diameter, inches	2$\frac{1}{2}$
length between tube sheets, feet and inches	5–8$\frac{1}{2}$
number of ordinary	158
number of stay	58
spaced vertically, inches	3$\frac{1}{2}$
spaced horizontally, inches	3$\frac{3}{4}$
thickness of ordinary, B.W.G. No. 12, inches	.109
thickness of stay, B.W.G. No. 6, inches	.203

Diameter of rivets in shell sheets, inch	1
Diameter of screw stays, inches	$1\frac{9}{16}$
Pitch of screw stays, inches	$6\frac{1}{2}$
Number and diameter of through upper braces, inches	8 of 2
lower braces, inches	2 of $1\frac{9}{16}$, 1 of $1\frac{1}{4}$
braces from head to back tube sheets, ins	2 of $2\frac{1}{2}$, 2 of $1\frac{9}{16}$
Heating surface, tube, square feet	824.67
furnaces, square feet	55.4
combustion chambers, square feet	96.25
total, square feet	976.32
Grate surface, square feet	32.
Area through tubes, square feet	5.43
over bridge walls, square feet	2.62
Volume of furnaces and combustion chambers above grates, cubic feet	104.58
Steam room, water six inches above tubes, cubic feet	114.
Water surface, water six inches above tubes, square feet	72.94
Smoke pipes (2), diameter, feet and inches	2-$3\frac{3}{4}$
area of both, square feet	8.4
height above lowest grates, feet and inches	46-7
Number and diameter of safety valves (2 on one base), inches	2 of 3
Diameter of boiler stop valves, inches	5.
Totals for two boilers:	
Heating surface, tube, square feet	1,649.34
furnaces, square feet	110.8
combustion chambers, square feet	192.5
total, square feet	1,952.64
Grate surface, square feet	64.
Area through tubes, square feet	10.86
over bridge walls, square feet	5.24
Volume of furnaces and combustion chambers above grates, cubic feet,	209.16
steam room, cubic feet	228.
Area of water surface, square feet	145.88
Ratios:	
Tube H.S. to G.S.	25.77 to 1
Furnace H.S. to G.S.	1.73 to 1
Combustion chamber H.S. to G.S.	3 to 1
Total H.S. to G.S.	30.51 to 1
Area through tubes to G.S.	.169 to 1
Steam room per square foot of G.S.	3.56 to 1
Volume of furnaces and combustion chambers above grates to G.S.	3.27 to 1
Totals for all boilers:	
Heating surface, tube, square feet	16,239.34
furnaces, square feet	1,090.8
combustion chambers, square feet	1,864.5
total, square feet	19,194.64
Grate surface, square feet	616.

Area through tubes, square feet	111.38
over bridge walls, square feet	67.48
Volume of furnaces and combustion chambers above grates, cubic feet	2,448.88
steam room, cubic feet	3,177.64
Area of water surface, square feet	1,102.76
Ratios of all boilers:	
Tube H S. to G.S.	26.36 to 1
Furnace H.S. to G.S.	1 77 to 1
Combustion chamber H.S. to G.S.	3.03 to 1
Total H.S. to G.S.	31.16 to 1
Area through tubes to G.S.	.181 to 1
Steam room per square foot of G.S.	5.16 to 1
Volume of furnaces and combustion chambers above grates to G.S.	3.97 to 1

Forced Draft.—The closed fire room system of forced draft is used. The air is supplied by ten Sturtevant blowers, one in each main and in each auxiliary fire room. The fans are driven by two-cylinder, vertical, simple, enclosed engines with cranks at 180 degrees.

BLOWERS IN MAIN FIRE ROOMS.

Diameter of steam cylinders, inches	5
Stroke, inches	4
Diameter of fan, inches	60
Width of fan at rim. inches	14
Area of induction nozzle, square inches	1,060.7
eduction nozzle, square inches	2,241

BLOWERS IN AUXILIARY FIRE ROOMS.

Diameter of steam cylinders, inches	3.5
Stroke, inches	2.5
Diameter of fan, inches	36
Width of fan at rim, inches	12
Area of induction nozzle, square inches	520.7
eduction nozzle, square inches	1,056

Feed Pumps.—In each feeding fire room of the main boilers, and in each fire room of the auxiliary boilers, there are two vertical, duplex, double acting Blake pumps, one for the main and one for the auxiliary feed. The main and auxiliary feed systems are not connected, but any pump can be used to feed any boiler. The main feed pumps draw from the feed tanks and deliver only to the boilers. The auxiliary feed pumps draw from the feed tanks,

sea, bilge, secondary drain pipe and boilers, and deliver into the boilers, fire main and overboard. The dimensions of the pumps in the main fire rooms are: Steam cylinders, 8 inches diameter; water cylinders, 5 inches diameter; stroke, 12 inches. The capacity of each pump is 200 gallons per minute. Those in the auxiliary fire rooms are: Steam cylinders, 6 inches diameter; water cylinders, 4⅛ inches diameter; stroke, 7 inches. The capacity of each pump is 100 gallons per minute.

Feed, Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, the bilge, the secondary drain pipe, the drainage cistern, the feed tanks and the air pump suctions, and delivers into the main and auxiliary feed pipes, the fire main and overboard. Their dimensions are: Steam cylinders, 12 inches diameter; water cylinders, 7 inches diameter; stroke, 12 inches. The capacity of each pump is 400 gallons per minute.

Fire and Bilge Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, the bilge, the secondary drain pipe and the drainage cistern, and delivers into the fire-main and overboard. Their dimensions are: Steam cylinders, 12 inches diameter; water cylinders, 7 inches diameter; stroke, 12 inches. The capacity of each pump is 400 gallons per minute.

Water Service Pumps.—In each engine room there is a vertical, duplex, double acting Blake pump which draws from the sea, and delivers into the water service pipes and fire-main. Their dimensions are: Steam cylinders, 8 inches diameter; water cylinders, 5 inches diameter; stroke, 12 inches. The capacity of each pump is 200 gallons per minute.

Ash Hoists.—In each main fire room hatch there is a Williamson double, reversible ash hoist, by means of which one bucket of ashes of 300 pounds (with a steam pressure of 60 pounds) can be hoisted in 5 seconds. The steam cylinders are 4½ inches in diameter, with a piston stroke of 4½ inches.

Grease Extractors.—There is a grease extractor in each feeding fire room. It is similar to a Macomb strainer; the basket is perforated and covered with burlap through which the water filters.

By-pass pipes and valves are fitted to feed the boilers while overhauling the extractor.

Feed Tanks.—There is a feed tank, of 1,000 gallons capacity, in each engine room. A part of the tank is fitted as a filter into which the water from the air pumps is delivered. The filter is provided with sponges, which are readily accessible. Each tank has a man-hole, glass water gauge, shut-off cocks, and drain cocks. An overflow pipe is fitted and so arranged that any water passing down it may be seen. Each feed pump suction is provided with a balanced valve operated by a copper float in the feed tank and so arranged that no air will enter the feed pipes.

Steam Traps.—The separators, the jackets, the main and auxiliary steam pipes, the radiators, and all places where condensed steam can accumulate are fitted with drain pipes and cocks, or valves, and with automatic traps which discharge into the feed tanks. The traps are provided with by-pass pipes and valves for convenience of overhauling.

Workshop.—The workshop is situated on a platform in the after part of the engine rooms. It is fitted with a vertical engine, 6 inches by 6 inches, a lathe, a shaping machine, a double-geared drilling machine, a grind stone and an emery wheel.

Distilling Apparatus.—There are two Baird distillers and two Baird evaporators with a maximum distilling capacity of 5,500 gallons of potable water in twenty-four hours; the ordinary capacity is 4,000 gallons. A Davidson pump (steam cylinder 4½ inches diameter; water cylinder 5 inches diameter; stroke 8 inches) is used to circulate the water through the distillers. After leaving the distillers the circulating water passes through the flushing pipes, and by-pass valves and pipes are fitted so that the water can enter the flushing pipes without passing through the distillers. A horizontal combined pump is used to feed the evaporators and to deliver the water from the filters to the ship's tanks; it has a steam cylinder 2½ inches diameter, water cylinders 1½ inches diameter, and a stroke of 3 inches. There is a pump to deliver the drain water from the evaporators into the feed tank; it has a steam cylinder 2½ inches diameter, a water cylinder 1½ inches diameter, and a stroke of 3 inches.

Ventilating Fans.—There is in each engine room a ventilating fan, which is used only for engine room service. For ventilating the ship generally, there are four fans situated on the orlop deck, and they are so arranged, by means of reversible valves, as to exhaust from, or force air to the various parts of the ship. The fans are driven by engines similar to those of the forced draft blowers.

Diameter of steam cylinders (2), inches	4
Stroke, inches	3
Diameter of fan, inches	48
Width of fan, inches	19

Steam Cutters.—There are two steam cutters, one 33 feet, and the other 30 feet long. They have Towne boilers, compound engines and keel condensers. The cylinders for the 33-foot cutter are 4 inches and 7 inches diameter by 7 inches stroke, and those for the 30-foot cutter, $3\frac{1}{2}$ inches and 7 inches diameter by 6 inches stroke.

Telegraphs and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in conning tower, pilot house and bridge, and a mechanical gong in each engine room with bell pulls at the steering wheels at after part of the superstructure deck. Mechanical tell-tales are fitted on the bridge and in the conning tower to show the direction of revolution of the main engines. In each engine room there are two mechanical indicators to show the speed and direction of revolution of each propeller. The two indicators are connected and each has two hands, a red one which turns with the port engine, and a green one which turns with the starboard engine. The hands can be turned on their shafts like the hands of a clock, so that by setting them together the relative speeds of the propellers can be seen as the hands separate or remain together in their revolutions over the dial of the indicator.

Telephones and Voice Pipes—For communication between the various parts of the ship there is a complete system of telephones, and voice pipes with call bells. The most important stations are connected direct with voice pipes, but for general purposes, in order to lessen the number of pipes, a central station is used.

Steering Engine.—On the after platform deck there is a Williamson combined hand and steam steering engine; cylinders, 13 inches diameter; stroke, 10 inches. The engine is connected to a horizontal fore-and-aft shaft, on the after end of which is a right-and-left-hand screw. The screw works in two crossheads, one on the starboard and one on the port side, and the rudder yoke is connected by rods to these crossheads. With the steam gear, the rudder can be put hard over from amidships in 10 seconds when the ship is going full speed.

Steam Windlass.—On the main deck forward there is a steam windlass, built by the American Ship Windlass Company, Providence, Rhode Island. The engine is reversible, double cylinder, vertical, direct acting, with cylinders 15 inches in diameter, and a stroke of 14 inches. The windlass is fitted with four wild cats to take the chains, also two drums or gypsies to take hawsers.

Steam Winches.—There are four double cylinder Williamson reversible winches or hoisting engines situated on the main deck, two forward and two aft. Each has one drum for wire rope and two gypsies for hawsers. Steam cylinders 8 inches diameter, stroke 8 inches. There are also two winches, of the same size as the above, situated on the superstructure deck, for hoisting boats.

Thirteen-inch Turret Turning Machinery.—Each 13-inch turret is turned by a double, horizontal engine, with cylinders 11½ inches diameter and 10 inches stroke. One engine is located in the compartment forward of the boilers, the other in the compartment abaft the engines. The turrets are turned by means of shafting and gearing, pinions on the top of the vertical shafting engaging a rack on the bottom of the turret. Each engine has a controlling valve, which is worked by means of shafting and gearing, from the sighting hood of the turret. Each turret can be turned through an angle of 270 degrees, and in order to prevent it from turning beyond its limits, automatic stop gear is provided which acts on the controlling valve. Provision is also made for turning by hand.

Eight-inch Turret Turning Machinery.—Each 8-inch turret is turned by a double, vertical engine, with cylinders 8 inches diame-

ter and 7 inches stroke, located in the ammunition passages on the orlop deck. A worm on the crank shaft of the engine engages a worm wheel on the lower end of the ammunition tube. Each engine is provided with a controlling valve, which can be operated at the engine, and also from the sighting hoods of the turrets by means of shafting and gearing. Automatic stop gear is provided to prevent the turrets from turning too far. In case the engine becomes disabled, provision is made for turning by hand.

Air Compressors.—There are two Rand air compressors for torpedo tubes situated on the orlop deck within the citadel, one forward and one aft. Each compressor has two steam cylinders, diameter 9 inches, stroke 4 inches. The air cylinders are above the steam cylinders and are enclosed in a chamber through which water circulates. The compressors are capable of making 200 revolutions per minute with 50 pounds steam pressure, the air pressure in the accumulator being 1,700 pounds to the inch.

Hydraulic Plant.—There is an hydraulic plant situated forward on the orlop deck within the citadel. It is used to elevate and depress the 13-inch guns, to load the guns, and also to hoist the ammunition for them. It consists of two horizontal, double acting duplex Blake pumps, an accumulator water tank, and the necessary piping. The combined capacity of the pumps is 1,000 gallons per minute, the working pressure being 600 pounds per square inch. This duty is done with 100 pounds steam pressure at the pump throttles. There is an accumulator consisting of a steam cylinder, a steam piston, and a water plunger. The steam piston is connected by means of shafting and levers to the throttle valves of the pumps.

The water tank has a capacity of 200 gallons, and fresh water only is used.

The delivery pipes are 4 inches in diameter and of wrought steel; the return pipes are 6 inches in diameter and of wrought iron. The flanges of the pipes are turned male and female and the joints made with leather gaskets. The delivery and return pipes lead to a double composition pipe casting around which a composition chamber revolves. The revolving chamber turns with the turret; it is divided into pressure and exhaust passages,

and the joints are made with cup-leather packing. The delivery and return pipes from the cylinders, for working the guns and hoisting the ammunition, are connected to the revolving chamber. All parts of the hydraulic system, except the suction, was tested to 1,200 pounds water pressure.

Steam cylinders, number	4
diameter, inches	24
stroke, inches	12
Water plungers, number	4
diameter, inches	8
stroke, inches	12
Accumulator steam cylinder, diameter, inches	28
water plunger, diameter, inches	10
stroke, inches	30

Electric Plant.—The installation consists in general of three generating sets, 500 incandescent lights, 4 search lights, 1 set of signalling apparatus, 2 stationary ventilating fans driven by electric motors, 4 portable ventilating fans driven by electric motors, 4 electric motors for 8-inch ammunition hoists, 1 main switch board, together with the necessary wire, wiring accessories, molding and fixtures.

The generating sets were made by the General Electric Company at Schenectady, N. Y. In each set there is a 24-kilo-watt dynamo of the multipolar type, having a capacity of 300 amperes at 80 volts, compound wound on 144 armature sections cross connected at 180 degrees. The engines driving the dynamos are two-cylinder vertical, inverted; diameter of cylinder, 10½ inches; stroke, 5 inches. The crank shaft and armature shaft are connected by a rigid coupling. The engines are designed to run, with full load, at 400 revolutions per minute with 80 pounds steam pressure. The bed plate is common to both engine and dynamo and measures 7 feet 3 inches by 3 feet 10 inches. The weight of each generating set (engine, dynamo and bed plate) is about 8,500 pounds. The incandescent lights are 10, 16 and 32-candle power designed for 80 volts.

There are four search lights, made by the General Electric Company; two mounted on the top of the pilot house, and two mounted in hammock berthing near the after end of the fore-and-

aft bridge. The projectors are 60 centimeters in diameter and electrically controlled. All lamps are horizontal combination, hand or automatic, and designed for a current of 80 amperes at about 50 volts. The carbon holders are adjustable, and the life of the carbon is six hours. Each search light has a power of about 25,000 candles.

The signal apparatus consists of four double signal lanterns, cable connection and key board. Each half of each double lantern is fitted with a fresnel lens, the upper lens being red. The key board is arranged to admit of thirty combinations of lights being made, each combination requiring but one motion to close the circuit.

There are two stationary ventilating fans, one arranged to force air into, and the other to exhaust the air from the dynamo room. Each fan is capable of delivering 2,200 cubic feet of air per minute at a speed of 1,570 revolutions, and is connected directly to a 2-horse power electric shunt motor.

There are four portable fans, to be used to exhaust the air from the double bottoms and various compartments. Each fan is capable of delivering 400 cubic feet of air per minute at a speed of 1863 revolutions, and is directly connected to a ¼-horse power electric series motor.

There is a standard Navy switchboard complete, containing the necessary connections, switches, cut-outs, &c., for 9 incandescent, 4 search light, and 3 motor circuits. It is provided with a pressure board, ground detector and measuring instruments. The pressure board has points connecting the volt meter with the terminals of each of the dynamos, and with each of the search light circuits. The ground detector is arranged to be thrown on either arc or incandescent circuit when operated separately.

Electric speed indicators and transmitters are fitted on the bridge, pilot house and in conning tower; also electric helm indicators.

There are water alarms in each bilge compartment, and thermostats in each coal bunker and paint room, with annunciators on bulkhead forward of cabin.

There are four 5-horse power electric motors for hoisting the ammunition for the 8-inch guns.

3	300-ampere generators, . . .		72,000 watts.
522	lights, 10, 16, 32-candle power,	25,775 watts.	
4	search lights, . . .	16,000 "	
	signalling apparatus, . .	96 "	
2	2-H.P. motors, . . .	2,984 "	
4	¼-H.P. motors, . . .	746 "	
4	5-H.P. motors, . . .	14,920 "	
		60,521 "	60,521 "
		Reserve power =	11,479 "

Ice Machine.—There is an Allen dense air machine capable of making one ton of ice per day, or 200 pounds of ice and at the same time keeping the refrigerating rooms near the freezing point, and cooling 300 gallons of water to 40 degrees Fahrenheit. Steam cylinder, 7 inches diameter; air compressor cylinder, 5¾ inches diameter; air expansion cylinder, 4⅝ inches diameter; stroke, 10 inches. The circulating water and primer pumps are single acting, each 1⅝ inches diameter and 10 inches stroke.

NUMBER OF ENGINES ON *INDIANA*.

Engines.	*Steam cylinders.*
2 main propelling engines, ...	6
2 main air pumps, ...	4
2 main circulating pumps, ...	2
2 auxiliary air and circulating pumps, ...	2
2 main reversing engines, ...	2
2 main turning engines, ...	4
1 workshop engine, ...	1
6 evaporator and distiller pumps, ...	6
1 oil pump, ...	2
2 feed, fire and bilge pumps, ...	4
2 fire and bilge pumps, ...	4
2 water service pumps, ...	4
4 main feed pumps for main boilers, ...	8
4 auxiliary feed pumps for main boilers, ...	8

Engines.	*Steam Cylinders.*
2 main feed pumps for auxiliary boilers,	4
2 auxiliary feed pumps for auxiliary boilers,	4
10 forced draft blowers,	20
2 ventilating blowers in engine room,	4
4 ventilating blowers for ship,	8
4 ash hoisting engines,	8
3 dynamo engines,	6
1 steering engine,	2
2 13-inch turret turning engines,	4
4 8-inch turret turning engines,	8
1 ice machine,	1
1 windlass and capstan engine,	2
6 winches,	12
2 hydraulic pumps,	4
1 accumulator,	1
2 air compressors for torpedo tubes,	4
1 pump for waste water tank,	1
2 steam cutter propelling engines,	4
2 steam cutter feed pumps,	4
86 Total	158

As the battery of the *Indiana* is placed well above the water line, it was expected that the ship would prove to be a heavy roller in a sea-way, and extensive preparations were made to record the degrees of roll. The first opportunity to test her sea qualities was off the capes of the Delaware. The sea was moderate, and while swinging ship to adjust compasses, it got abeam. Instead of rolling, the ship remained perfectly steady, and the seas spent their force against her side. On the return from the official speed trial, a stiff breeze and rough sea were encountered, and still she remained steady, except a slight pitching, which, however, was not deep. The greatest roll recorded was 1½ degrees, so that the ship will prove an excellent gun platform.

In comparing the *Indiana* with the battle-ships of foreign navies it is found that the former is inferior in only one respect, that of speed. This important feature was slightly sacrificed in

order to obtain a heavy armament. As she is intended to defend the coast line, she would be nearer her base in time of war, and hence would, in all probability, have a cleaner bottom than foreign vessels, so that her speed would be very little, if any, less. And, furthermore, her boiler power is as large as that of larger foreign battle-ships, which are credited with greater speed; so that it is fair to infer that, even in this particular, she is little, if at all, inferior to them.

OFFICIAL SPEED TRIAL.

The official speed trial took place off the New England coast on October 18, 1895. It consisted of two runs over a measured course of 31 nautical miles. The average speed of the two runs was 15.547 knots per hour. The sea was moderate, the wind was abeam and blew with a force of 4 to 5 on the Beaufort scale. All boilers were in use under forced draft. All the steam generated was used by the main engines and auxiliaries, except that used in the steering engine and in the engine for the dynamo to light the engine and boiler compartments. The coal used was selected Pocahontas. The boilers steamed freely and steadily, and showed no evidence of priming. The main engines worked well and without vibration. No water was used on the engines, except what circulated through the crank shaft brasses and caps and crosshead guides. The air and circulating pumps worked well and required no special attention, except that of oiling.

After the trial the boilers, main engines and auxiliaries were examined and found in good condition.

DATA OF OFFICIAL TRIAL.

Draught, mean for trial, forward, feet	23.69
aft, feet	24.06
Displacement at mean draught on trial, tons	10,225
Area of immersed midship section, square feet	1,540
Wetted surface, square feet	30,500
I.H.P. (total) per 100 square feet of wetted surface	31.93
at 10 knots, reduced in ratio of 3.5 power	6.814
Average speed in knots	15.547
Slip (mean of both screws), per cent	24.85
Speed $^{3}\times$ area of immersed midship section $\div$ I.H.P	606 28
displacement$^{\frac{2}{3}}$ $\div$ I.H.P	185.47

SYNOPOSIS OF STEAM LOG.

	Starboard.	*Port.*
Revolutions of main engines per minute, mean	130.79	131.25
Piston speed in feet, per minute	915.53	918.75
Steam pressure at boilers, per gauge	166.53	
engines, per gauge	163.6	165.
1st receiver, absolute	70.39	75.61
2d receiver, absolute	25.55	25.83
Vacuum in condensers, inches of mercury	24.68	24.68
Opening of throttle	wide.	
Steam cut-off in fractions of stroke from beginning, H.P	.634	.640
I.P	.699	.667
L.P	.718	.708
Double strokes of air pump, per minute	31.65	29.75
Revolutions of circulating pumps per minute	247.4	170.2
Temperatures in degrees, Fahrenheit, engine room	77	79
injection	50	50
discharge	102	119
hot well	108	85
feed	107	109
fire rooms	101	
Air pressure, in inches, of water in fire rooms	.955	
Revolutions of blowers per minute, fire rooms	398.4	
engine rooms	236.23	
Mean pressures in cylinders, H.P	65.031	57.315
I.P	31.598	33.55
L.P	13.1854	12.623
equivalent reduced to L.P	39.37	37.98
I.H.P.:		
H.P. cylinder	1,644.64	1,454.06
I.P. cylinder	1,575.57	1,672.25
L.P. cylinder	1,605.68	1,545.80
Collective, each main engine	4,825.89	4,672.11
both main engines	9,498	
Air pumps	11.048	9.367
Circulating pumps	19.51	7.234
Feed pumps	74.607	
Blowers, forced draft	52.808	
Other auxiliaries	65.917	
Collective I.H.P. of all auxiliaries	240.491	
main engines, air and circulating pumps,	9,545.159	
all machinery in operation	9,738.491	
Indicated thrust (main engines only), pounds	76,102.13	73,418.87
per square foot of developed area of propellers, pounds	1,412.99	1,363.16
Indicated thrust per square inch of thrust bearing, pounds	34.96	33.73

	Starboard.	*Port.*
Cubic feet swept per minute by L.P. piston per I.H.P.	5.82	6.03
Square feet of cooling surface per I.H.P	1 387	
total heating surface per I.H.P.	1.971	
I.H.P. per square foot of G.S. (all machinery in operation)	15.8	

COAL CONSUMPTION TRIAL.

The coal consumption trial was for six hours, with the two after main boilers under forced draft.

	Starboard.	*Port.*
Revolutions of main engines per minute	95 97	95.4
Piston speed, in feet, per minute	671.79	667.8
Steam pressure at boilers, per gauge	152.37	
engines, per gauge	150 5	150.21
1st receivers, absolute	34.3	36.28
2d receivers, absolute	16 57	17.43
Vacuum in condensers, inches of mercury	24 19	24.57
Opening of throttle, holes	1	.8
Steam cut-off in fractions of stroke from beginning: H.P.	.474	.428
I.P.	.699	.667
L.P.	.718	.708
Double strokes of air pumps per minute	21 66	22.14
Revolutions of circulating pumps per minute	194.66	158.14
Temperatures, in degrees, Fahrenheit: engine rooms	89	89
injection	55	55
discharge	123	128
feed	124	130
fire rooms	120	
Air pressure, in inches, of water in fire rooms	1.04	
Revolutions of blowers per minute: fire rooms	406	
engine rooms	175	
Mean pressures in cylinders:		
H.P.	38.049	37.383
I.P.	11.314	12.357
L.P.	7.034	6.779
Equivalent reduced to L.P	19.499	19.563
I.H.P.:		
H.P. cylinder	705.78	689.48
I.P. cylinder	410.51	444.425
L.P. cylinder	629.74	603.42
Collective, each main engine	1,746.03	1,740.325
both main engines	3,486.355	
Air pumps	3.541	3.961
Circulating pumps	9.755	5.788
Feed pumps	57.224	

t.
03

ter

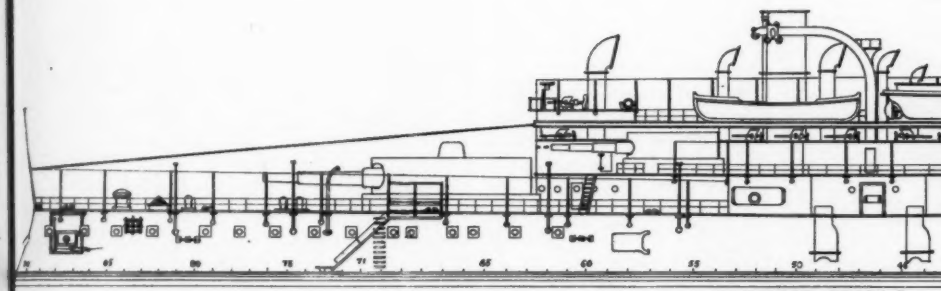
t.
4
8

21
28
43
57
8
428
667
708
14
14

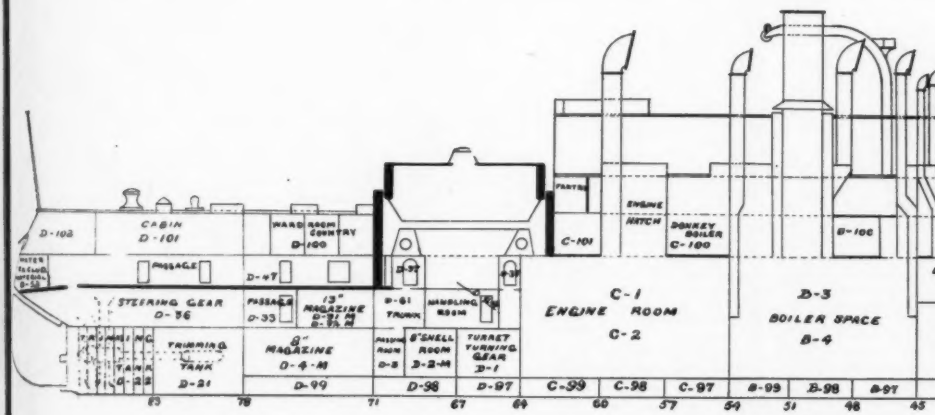
383
357
779
563

48
425
42
325

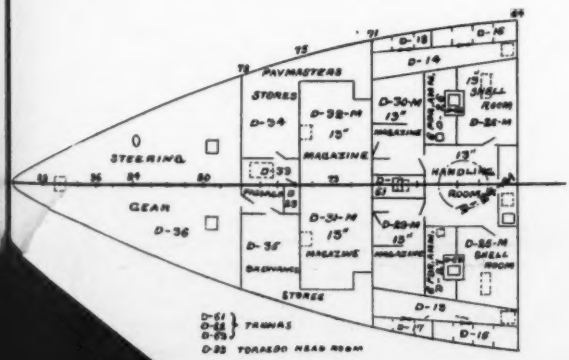
961
788



— OUTBOARD PROFILE —

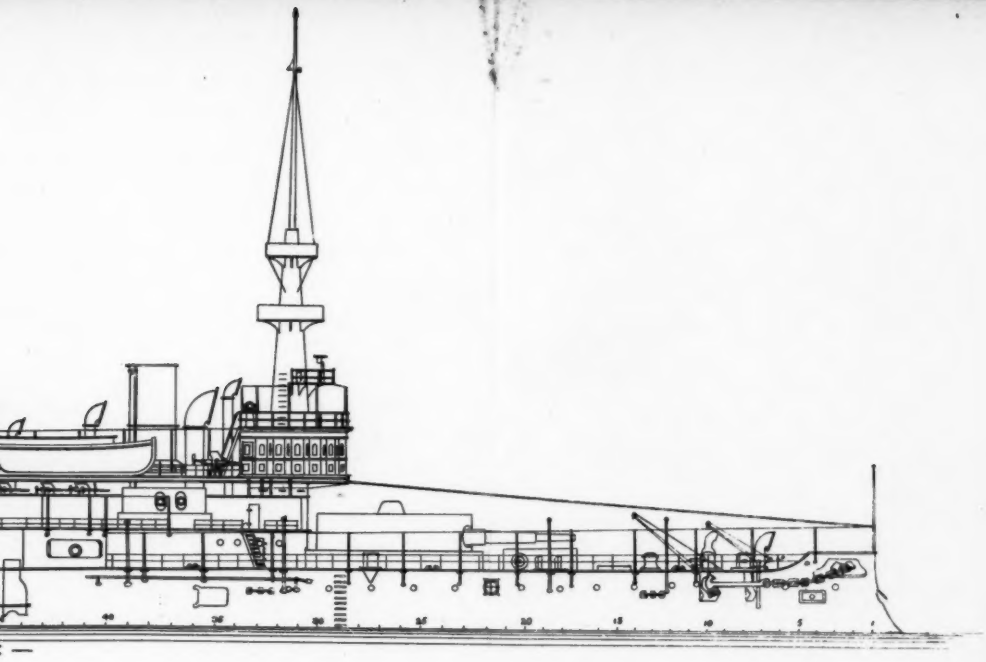


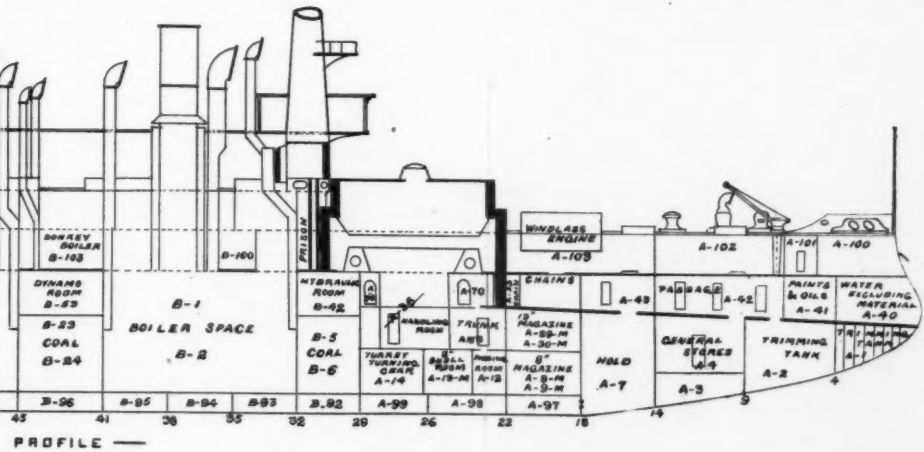
— INBOARD PR



LENGTH BETWEEN PE
LENGTH EXTREME-
BREADTH EXTREME
MEAN DRAFT -----
TONS DISPLACEMENT

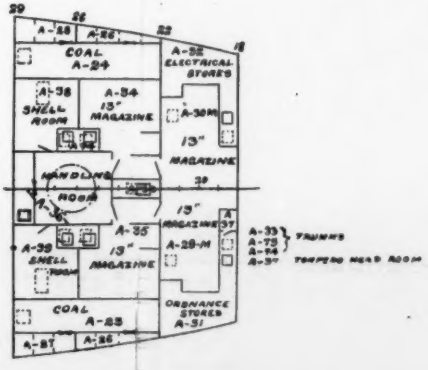
— PLATFORI



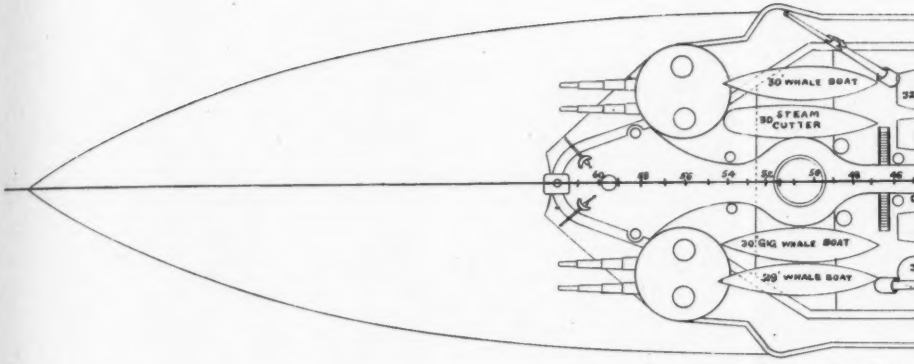


PROFILE ——

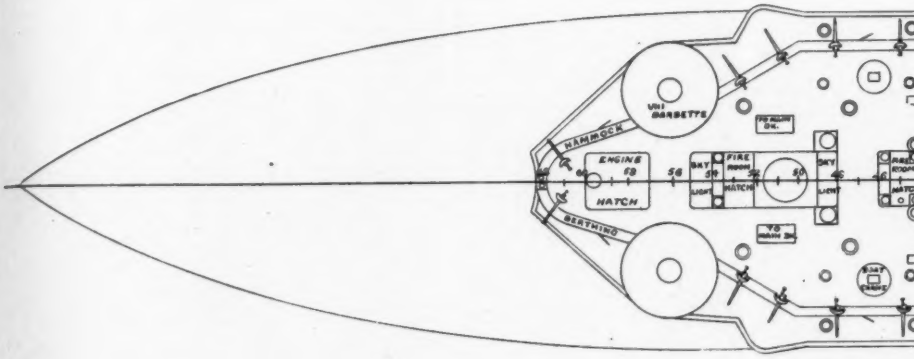
PERPENDICULARS ----- 348 FT.
E ----------- 350 "
ME ----------- 69 FT. 3 IN.
---------- 24 FT.
ENT AT 24 FT. W. L ---- 10225.



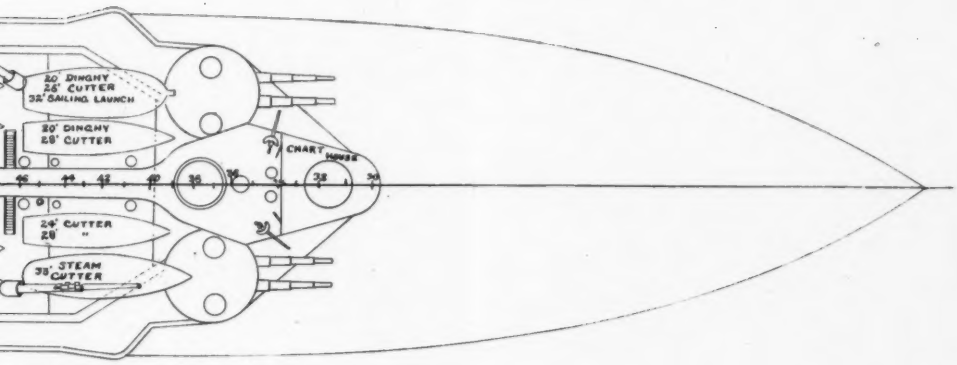
ORMS ——

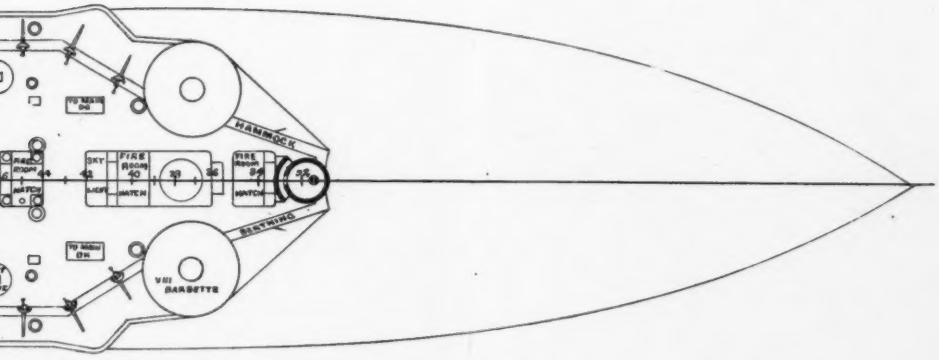


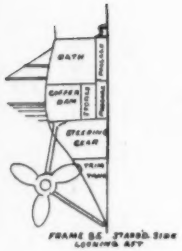
— BRIDGE DE



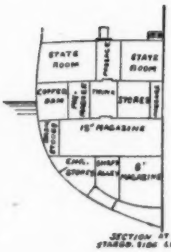
— UPPER DEC


20' DINGHY
26' CUTTER
32' SAILING LAUNCH
20' DINGHY
26' CUTTER
CHART HOUSE
24' CUTTER
28' "
38' STEAM
CUTTER
DECK

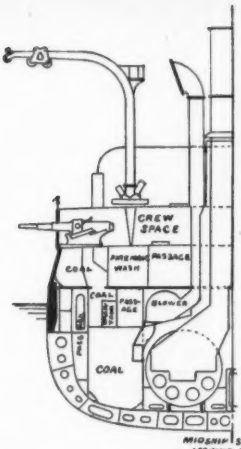

HAMMOCK
SKY
FIRE ROOM
MATCH
BREATHING
VIII
BARBETTE
ECK



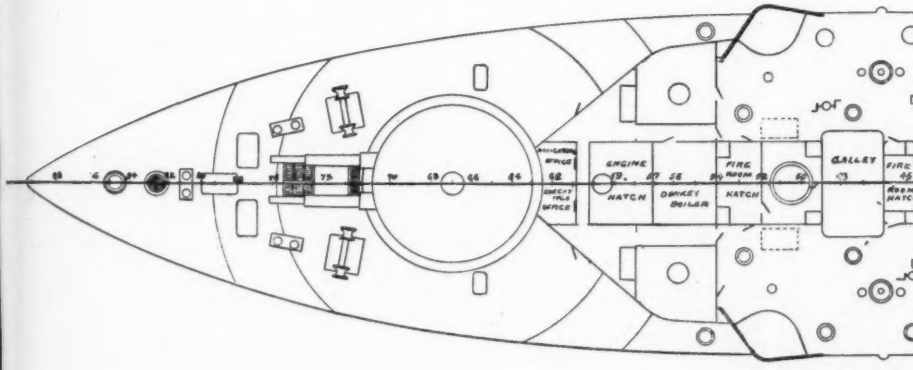
FRAME 96 STARBD. SIDE LOOKING AFT



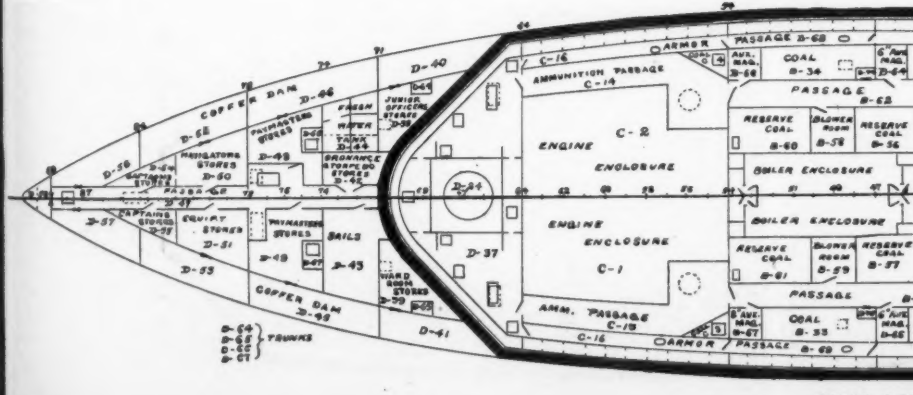
SECTION AT 75 STARBD. SIDE LOOKING AFT



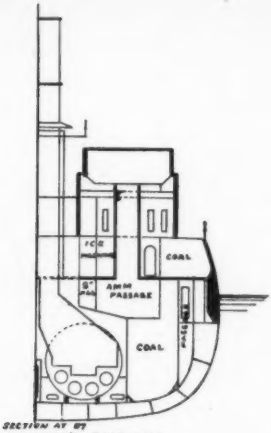
MIDSHIP SECTION LOOKING AFT STARBD



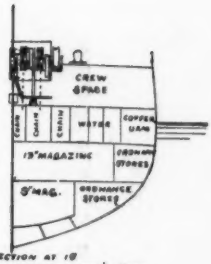
—— MAIN DEC



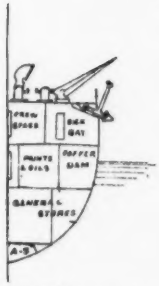
—— ORLOP DEC



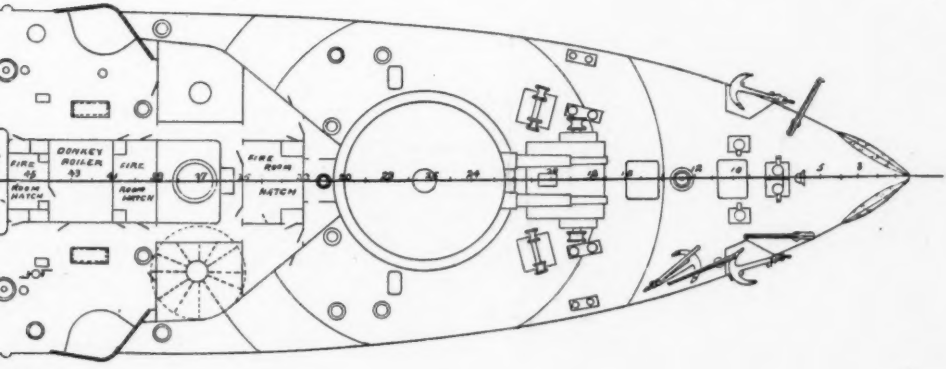
SECTION AT 67
LOOKING FORD. STARBD. SIDE



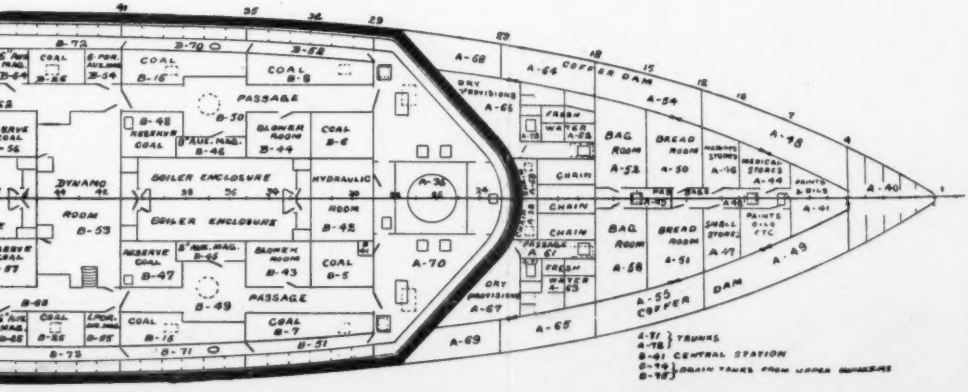
SECTION AT 18
LOOKING FORD. STARBD SIDE



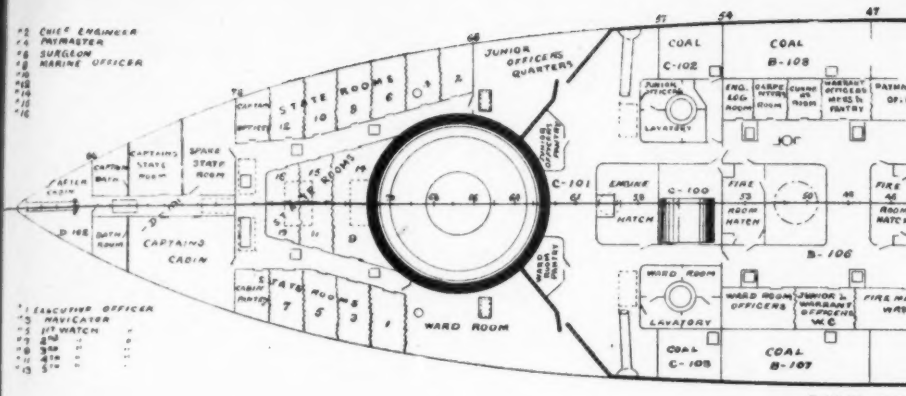
SECTION AT 9
LOOKING FORD. STARBD. SIDE



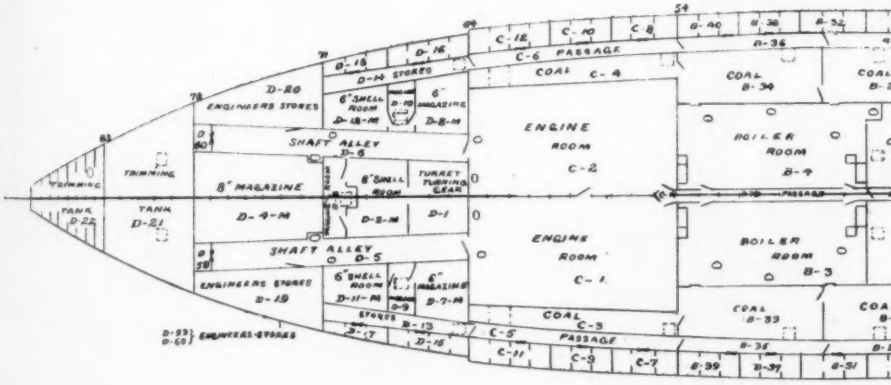
CDECK —



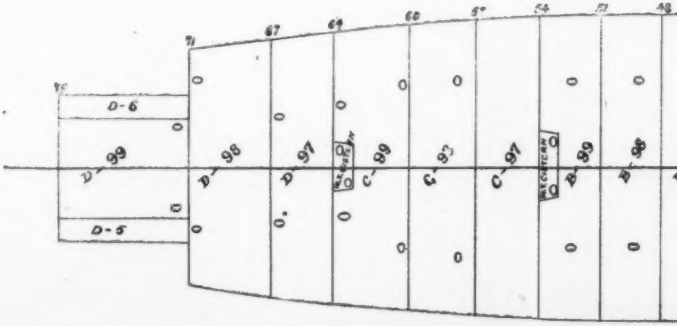
DECK AND PASSAGES —



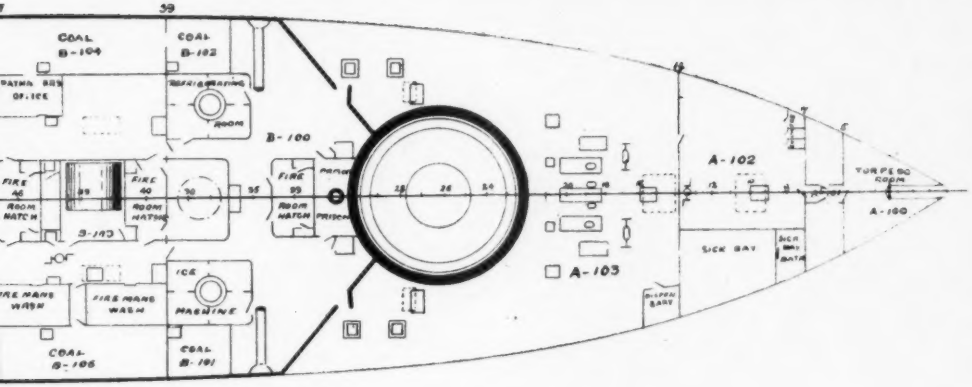
— BERTH DE



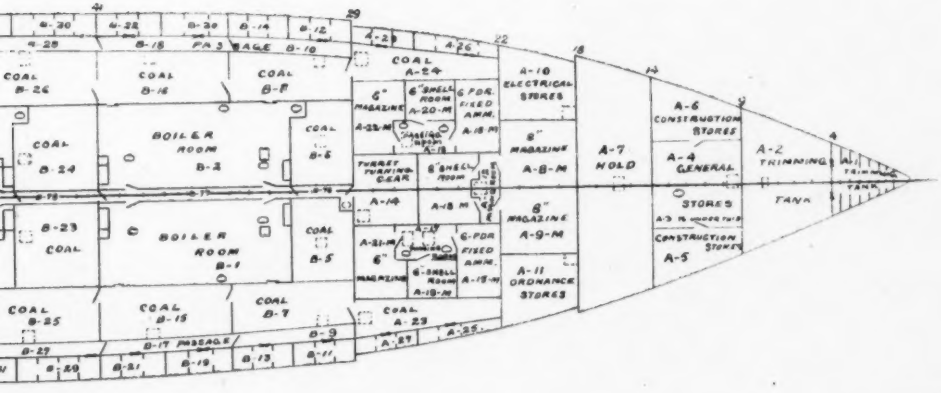
— HOLD —

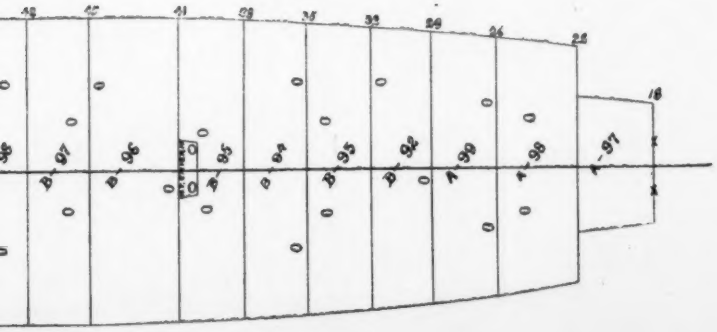


— INNER BOTT


COAL B-104
COAL B-102
B-100
A-102
A-103
A-100
TORPEDO ROOM
SICK BAY
FIRE ROOM HATCH
B-103
ICE MACHINE
FIRE MAIN WASH
COAL B-105
COAL B-101

DECK —

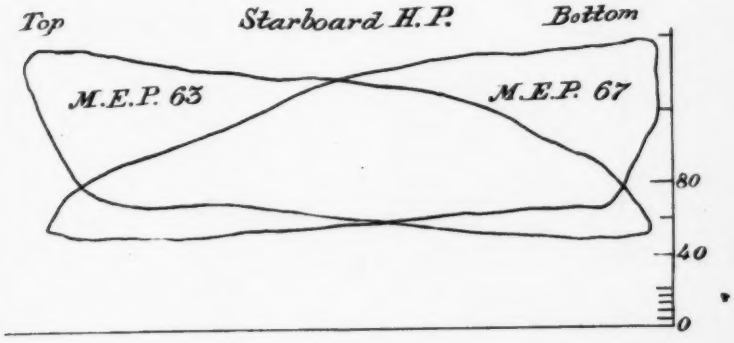

COAL B-26
COAL B-16
COAL B-6
COAL A-24
BOILER ROOM B-2
BOILER ROOM B-1
COAL B-24
COAL B-23
COAL B-25
COAL B-15
COAL B-7
COAL B-5
COAL A-23
6" MAGAZINE
6" SHELL ROOM
6 PDR. FIXED AMM.
TURRET TURNING GEAR
A-18 ELECTRICAL STORES
8" MAGAZINE A-8-M
8" MAGAZINE A-9-M
A-11 ORDNANCE STORES
A-7 HOLD
A-6 CONSTRUCTION STORES
A-4 GENERAL STORES
CONSTRUCTION STORES A-5
A-2 TRIMMING TANK

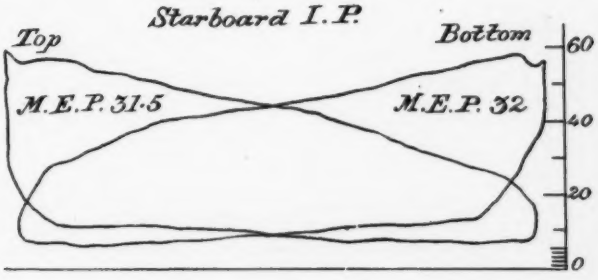

B-97
B-96
B-95
B-94
B-93
A-99
A-98
A-97

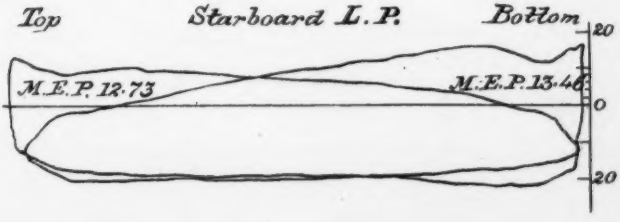
BOTTOM —

U. S. S. Indiana.

Vacuum	*24.68*
Revolutions	*130.79*

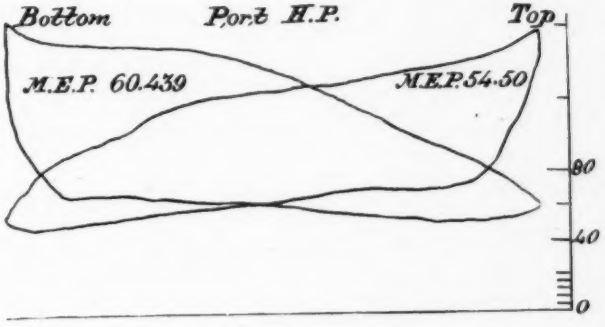


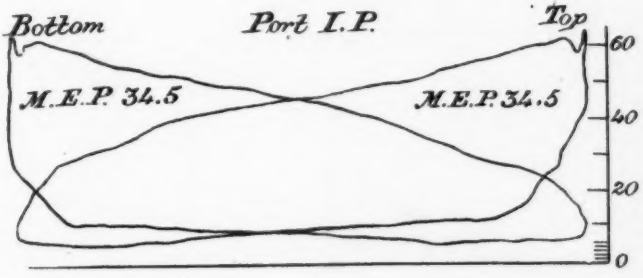


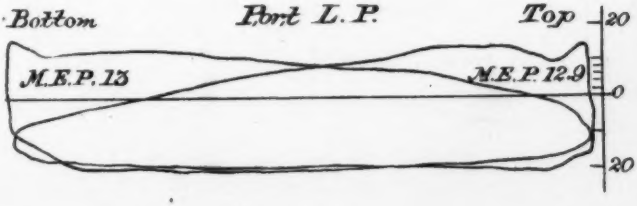


U.S.S. Indiana.

Vacuum 24.79
Revolutions 131.25



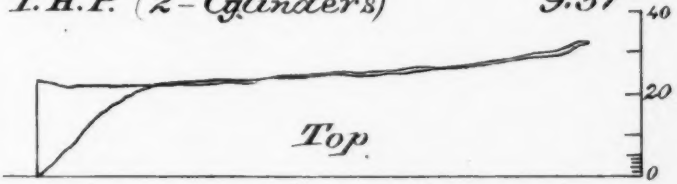




U. S. S. Indiana

Port Air Pump Cards.

Double Strokes	*29.75*
Vacuum	*24.75 ins.*
Steam Pressure	*161 lbs.*
Scale	*40 lbs.*
I.H.P. (2-Cylinders)	*9.37*



I.H.P.:	*Starboard.*	*Port.*
Blowers, forced draft	24.768	
Other auxiliaries	40.96	
Collective I.H.P. of all auxiliaries	145.997	
main engines, air and circulating pumps	3,509.4	
all machinery in operation	3,632.352	
Square feet of heating surface in use	8,621	
grate surface in use	276	
Quality and kind of coal	selected Pocahontas.	
Coal burned per hour, actual weight, pounds	7,347.57	
per square foot of grate surface	26.62	
per square foot of heating surface	.852	
per I.H.P. of all machinery	2.022	
per I.H.P. of main engines, air and circulating pumps	2.093	

THE STEAM-YACHT *YOSEMITE.*

By Chief Engineer Isherwood, U. S. Navy.

The *Yosemite* was a large and very elegant iron steam-yacht, the hull and appointments of which were designed by the late Mr. Edward Faron, formerly a United States Naval Engineer, and at that time the Superintendent of the Delaware River Iron Ship Building and Engine Works, at Chester, Delaware county, Pennsylvania, where the yacht was built by John Roach & Son, the proprietors of those works at that time.

The machinery was designed by the late Mr. Henri Leverat, at that time the engineer and superintendent of the Morgan Iron Works, in the city of New York, where it was constructed by John Roach & Son, the proprietors of the works.

The *Yosemite* in hull, machinery and appointments, was in all respects of design, execution, accommodations and speed, a first-class sea-going yacht, containing all the latest improvements. She was perfectly safe and comfortable for the most extended sea voyages and in the worst weather. The hull was not sheathed, and had a very light schooner rig. About 200 tons of coal were carried in the bunkers when the latter were filled.

During July and August of 1884, Mr. Roach placed the *Yosemite* at the command of the Secretary of the Navy for his personal use and to show the high speed and general efficiency that could be given to a sea-going vessel of her relatively small dimensions. She made under these circumstances a voyage from New York City to Portsmouth, New Hampshire, *via* Newport, Rhode Island; and thence back to New York, a distance of about 650 geographical miles in Long Island Sound and at sea, having been experimented with during this time by a Board of Naval Officers embracing among others the Chief of the Bureau of Steam Engineering in the Navy Department, who

caused the notes and indicator diagrams to be taken during a trial of four consecutive runs, with maximum speed, over the measured geographical mile in Narragansett Bay, near Newport, and during an extended run at sea with medium speed between Wood's Holl, Massachusetts, and Portsmouth, New Hampshire, from which the calculations have been made that will be found in the table hereinafter given under the head of "Performance." Previous to this table are given the dimensions of the hull and machinery of the vessel, as follows:

HULL.

The hull was of iron and had the following dimensions:

Extreme length, feet and inches	197–6
Length on load water line from forward edge of stem to after edge of stern-post, feet and inches	176–8½
Extreme breadth on load water line, feet	24
Depth of keel below plating, inches	11
Depth from load water line to bottom of plating, feet and inch	10–1
Load draught of water from bottom of keel, forward, feet	10
Load draught of water from bottom of keel, mean, feet	11
Load draught of water from bottom of keel, aft, feet	12
Area of the greatest immersed transverse section, square feet	160.62
Area of the load water section, square feet	2,932.00
Area of the immersed or wetted surface of the hull, exclusive of keel and rudder, square feet	4,522.52
Area of the wetted surface of the keel, square feet	271.36
Area of the wetted surface of the rudder, square feet	66.80
Aggregate area of the wetted surface of hull, keel and rudder, square feet	4,860.68
Displacement to load water section, cubic feet	16,023.00
Displacement to load water section, tons	458.69
Displacement at load water section per inch of draught of water, tons	6.99
Angle of dead rise amidship, degrees	16¼
Angle of entrance of load water section at end of bow, degress and min.,	3–39
Greatest obliquity of load water section at entrance, degrees and minutes,	12–41
Ratio of the length on the load water line from forward edge of stem to after edge of stern post, to the extreme breadth on load water line	7.363
Ratio of the greatest immersed transverse section to its circumscribing parallelogram	0.664
Ratio of the load water section to its circumscribing parallelogram	0.691
Ratio of the load displacement to its circumscribing parallelopipedon	0.375
Ratio of the displacement to a solid having the greatest immersed transverse section for base, and the length on the load water line from forward edge of stem to after edge of stern post for height	0.564

ENGINE.

There was one compound engine, consisting of one small cylinder and two large cylinders, the latter being duplicates; and all three cylinders had the same stroke of piston, and the same diameter of piston rod, which rod was on the lower side of the pistons only.

The engine had one surface condenser and one air pump; the axes of the three cylinders were vertical and in the same plane with the axis of the crankshaft. The air pump was vertical and single acting, as were also the feed pump and the bilge pump. All three pumps were worked from a reducing beam or lever which received its motion from a main crosshead, their strokes of piston being one inch longer than half the stroke of the steam pistons. The steam cylinders were *not* steam jacketed, and each was fitted with a variable Meyer cut off valve working on the back of the steam valves. All the cylinder valves were slides worked by eccentrics; the steam valves were fitted with the Stephenson Link as a reversing gear.

The injection or condensing water was supplied to the condenser by a centrifugal or fan pump (Gerick's patent) which drives the water through the tubes, the latter being surrounded by the exhaust steam from the two large cylinders. This pump was driven by a small independent steam cylinder, which exhausted into the condenser.

The following are the dimensions of the principal details of the engine:

Number of small cylinders	1
Number of large cylinders	2
Diameter of the small cylinder, inches	28½
Diameter of the piston rod of the small cylinder, inches	5
Net area of the small cylinder, exclusive of area of piston rod, square ins.,	630.122
Stroke of the piston of the small cylinder, inches	33
Space displacement of the piston of the small cylinder per stroke, cubic ft.,	12.034
Space in the clearance and steam passage at one end of the small cylinder, cubic feet	0.904
Number of steam ports at each end of the small cylinder	2
Breadth of each steam port at each end of the small cylinder, inches	2
Length of each steam port at each end of the small cylinder, inches	16

Aggregate area of the two steam ports at each end of the small cylinder, square inches	64
Diameter of the large cylinders, inches	40
Diameter of the piston rod of the large cylinders, inches	5
Aggregate net area of the two large cylinders, exclusive of the area of their piston rods, square inches	2,493.639
Stroke of the pistons of the two large cylinders, inches	33
Aggregate space displacement of the pistons of the two large cylinders, per stroke, cubic feet	47.622
Aggregate space in the clearances and steam passages at one end of the two large cylinders, cubic feet	3.663
Number of steam ports at each end of each large cylinder	2
Breadth of each steam port at each end of each large cylinder, inches	2
Length of each steam port at each end of each large cylinder, inches	28¾
Aggregate area of the two steam ports at each end of the two large cylinders, square inches	115
Clearance of the small and of the large cylinders at their top, inch	½
Clearance of the small and of the large cylinders at their bottom, inch	¾
Fraction of the space displacement of the piston of the small cylinder per stroke in the clearance and steam passage at one end	0.075
Fraction of the aggregate displacements of the pistons of the two large cylinders per stroke, in the aggregate clearances and steam passages at one end	0.077
Ratio of the aggregate net areas of the two large cylinders to the net area of the small cylinder	3.957
Ratio of the aggregate displacements per stroke of the pistons of the two large clyinders plus the aggregate spaces in the clearances and steam passages at one end of these cylinders, to the space displacement per stroke of the piston of the small cylinder plus the space in the clearance and steam passage at one end of this cylinder	3.964
Diameter of crosshead journal, inches	6
Length of crosshead journal, inches	8
Length of crosshead guide-gib (slipper guide), inches	21
Breadth of crosshead guide gib, inches	14½
Area of crosshead guide gib, square inches	304½
Length of connecting rod between centers, feet	6
Diameter of connecting rod neck, at crosshead end, inches	5
Diameter of connecting rod neck, at crankpin end, inches	5½
Number of main or crankshaft journals	6
Diameter of crankshaft journals, inches	10
Length of the two crankshaft journals that are outside of frame, inches	15
Length of the four crankshaft journals that are inside of frame, inches	11
Diameter of crankpin journal, inches	9
Length of crankpin journal, inches	12
Diameter of line shaft journals, inches	9½
Length of line shaft journals, inches	14

Breadth of eccentric strap for small cylinder, inches	3½
Breadth of eccentric strap for the two large cylinders, inches	4¾
Diameter of feed pump plunger, inches	3½
Stroke of feed pump plunger, inches	17
Displacement of the feed pump plunger per stroke, cubic foot	0.087
Diameter of air pump (one and single acting), inches	20
Diameter of air pump piston rod, inches	3
Stroke of air pump piston, inches	17
Space displacement of the air pump piston per stroke, cubic feet	3.021
Number of tubes (brass) in the surface condenser	1,526
Length, between plates, of the tubes in the surface condenser, inches	80
Outside diameter of the tubes in the surface condenser, inch	⅝
Aggregate condensing surface of the tubes in the surface condenser, sq. ft.	1,664.612
Diameter of the steam cylinder driving the centrifugal pump which supplied the condensing or injection water, inches	8
Stroke of the piston of the steam cylinder driving the centrifugal pump which supplied the condensing or injection water, inches	9
Diameter of the centrifugal pump supplying the injection water, inches	30

BOILERS.

The boilers were two in number, placed side by side, with the fireroom in the athwartship direction. The uptakes of both boilers discharge into the same chimney, the lower portion of which is surrounded by an annular steam drum or "steam chimney" whose interior surface is thereby made steam superheating surface. The natural draft of the boilers was sufficient, with anthracite, for supplying steam for all ordinary speeds—say, up to 13 geographical miles per hour; but for speeds higher than that, and for the maximum performance, the combustion of the anthracite was forced by a fan blower delivering its air into closed ashpits. There was only one blower, and it was driven by one independent steam cylinder directly attached, that is, driving the fan without belt or other gearing. The exhaust steam from this cylinder was delivered into the surface condenser.

The boilers were of steel, cylindrical, with shells $\frac{11}{16}$-inch thick. Each boiler contained three cylindrical furnaces.

The tubes were of iron, and were returned above the furnaces in the usual manner.

The following are the principal dimensions and proportions of the boilers:

Number of boilers	2
Diameter of boilers, feet and inches	12-2
Length of boilers (exclusive of uptake), feet	11
Total number of furnaces	6
Diameter of each furnace, feet and inches	3-4
Length of grate bars, feet and inches	7-4½
Total area of grate surface, square feet	149
Number of tubes (iron) in each boiler	188
Outside diameter of boiler tubes, inches	3½
Inside diameter of boiler tubes, inches	3.012
Length of boiler tubes, feet and inches	7.9
Total area of heating surface in boiler tubes calculated for their outside diameter, square feet	2,479.4
Total area of heating surface in boiler tubes calculated for their inside diameter, square feet	2,297.8
Total cross area of boiler tubes for draught, square feet	18.605
Height of chimney above the level of the grates, feet	50
Diameter of the chimney, elsewhere than in the steam drum, feet and inches,	5.5
Cross area of the chimney in the steam drum, square feet	18.665
Outside diameter of the steam drum, feet	8
Inside diameter of the steam drum, feet and inches	4-10½
Height of the steam drum above the shell, feet	7
Steam superheating surface in the steam drum, square feet	107.207
Steam superheating surface in the two uptakes, square feet	19.793
Total steam superheating surface, square feet	127.000
Total water heating surface in the boilers, calculated for the outside diameter of the tubes, square feet	3,220.0
Total water heating surface in the boilers, calculated for the inside diameter of the tubes, square feet	3,038.4
Square feet of water heating surface, calculated for the outside diameter of the tubes per square foot of grate surface	21.611
Square feet of water heating surface, calculated for the inside diameter of the tubes per square foot of grate surface	20.392
Square feet of steam superheating surface per square foot of grate surface	0.852
Square feet of grate surface per square foot of cross area of tubes for draft	8.009
Square feet of grate surface per square foot of the cross area of the chimney in the steam drum	7.982
Number of fan blowers	1
Number of steam cylinders driving the fan blower	1
Diameter of steam cylinder driving the fan blower, inches	7
Stroke of the piston of the steam cylinder driving the fan blower, inches	7

SCREW.

There was one cast-iron screw of the Hirsch form with the pitch expanding uniformly from the front edges to the back edges of the blades.

Diameter of the screw, feet	11
Diameter of the hub, feet	1.75
Pitch at the front edge of the blades, feet	15.50
Pitch at the back edge of the blades, feet	18.50
Mean pitch of the screw, feet	17.00
Number of blades	4
Length of the blades at the hub in the direction of the axis, feet	2.125
Length of the blades at the periphery in the direction of the axis, foot	0.500
Aggregate helicoidal surface of the blades, square feet	38.346
Aggregate projected surface of the blades on a plane at right angles to the axis, square feet	26.827
Fraction used of the pitch (17 feet)	0.300
Thickness of the blades at the fillet of the hub, inches	6½
Thickness of the blades at the periphery, inch	¾

EXPLANATION OF THE TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS.

The following table contains the data and results of the two experiments made with the *Yosemite.* The first experiment was made to ascertain the maximum speed that could be given to the vessel during four consecutive runs over a measured base of one geographical mile, by forcing the combustion of anthracite in the furnaces by means of a Sturtevant blower driven at its maximum and delivering air into the closed ash pits. Two sets of indicator diagrams, from top and bottom of cylinders, were taken on each mile, making eight sets in all, from which the quantities in the table are obtained.

The second experiment consisted of a run at sea of 12 hours and 27 minutes consecutively, in smooth water and nearly calm air between lighthouses, burning anthracite with the natural draught of the boilers and at the lowest practicable rate of combustion that would keep the grates covered with ignited coal. During this experiment the weight of anthracite consumed was carefully ascertained. The indicator diagrams were taken every twenty minutes. The fires were not cleaned during the run, and all the conditions were such as to produce the power with the greatest possible economy of fuel.

The bottom of the vessel was perfectly smooth and clean, having been scraped and painted only a few days before the experiments were made.

In the following table, the different quantities are grouped as they stand in natural relation, and the lines containing them are numbered for facility of reference.

Vessel.—Lines 1 to 6, both inclusive, contain respectively, the vessel's draught of water during the experiments, and the greatest immersed transverse section, the displacement, and the external immersed surface corresponding thereto.

Engine.—Line 7 contains the mean steam pressure in the boilers in pounds per square inch above the atmosphere; and line 8 contains the mean steam pressure in the receiver between the small cylinder and the two large cylinders, in pounds per square inch above the atmosphere.

Lines 9 and 10 contain respectively the fractions of the stroke of the steam pistons, measured from the commencement of the stroke, on the indicator diagrams at the point where the throttled curve changes into the reversed expansion curve, at which the steam is cut off in the small cylinder and in the large cylinders. The cut off valve was so set on all the cylinders that the cutting off of the steam took place at the same point of the stroke of all the steam pistons.

Line 11 gives the number of times the steam was expanded by volumes. The expansion in the small cylinder was first ascertained by dividing the space displacement of its piston per stroke plus the space in the clearance and steam passage, by the space displacement of its piston per stroke up to the point of cutting off plus the space in the clearance and steam passage, and multiplying the quotient by the ratio which the space displacement of the pistons of the two large cylinders per stroke plus the space in their clearances and steam passages at one end, is to the space displacement of the piston of the small cylinder per stroke plus the space in the clearance and steam passage.

Line 12 gives the vacuum in the surface condenser in inches of mercury; that is to say, the difference between the atmospheric pressure and the pressure in the condenser.

Line 13 gives the pressure in the condenser in pounds per square inch above zero, assuming zero to be 14.688 pounds per square inch below the atmospheric pressure.

Line 14 gives the number of double strokes made by the pistons of the engine, or of revolutions made by the screw, per minute.

Speed.—Lines 15 and 16 show the speed of the vessel, respectively, in statute miles, of 5,280 feet per hour, and in geographical miles of 6,086 feet. The speed in both experiments is absolutely accurate, being obtained from fixed landmarks.

Line 17 shows the slip of the screw in per centum of the axial speed of its form, calculated for the final pitch of 18.50 feet, and *not* from its *mean* pitch. The true slip is the speed imparted to the water by the screw. All the water that passes over the screw leaves it with a velocity equal to the difference between the axial speed of the final pitch and the speed of the vessel. The previous pitches—down to the initial pitch—gradually increase the horizontal speed of the water acted on by the screw from the front edge to the back edge of its blades, and thus assist in the propulsion of the vessel; but the speed ultimately obtained is that which is due to the final pitch, and with this speed the whole mass of water acted on by the screw leaves it.

Steam Pressures in the Small Cylinder per Indicator.—Lines 18 to 27, both inclusive, contain the various steam pressures in the small cylinder, as given by the means obtained from all the indicator diagrams.

Lines 18, 19 and 20 contain, respectively, the steam pressures on the piston of the small cylinder at the commencement of its stroke, at the point of cutting off the steam, and at the end of its stroke, in pounds per square inch above zero.

Line 21 contains the mean back pressure, including cushioning, against the piston of the small cylinder during its stroke, in pounds per square inch above zero.

Line 22 contains the back pressure in pounds per square inch above zero against the piston of the small cylinder at the point (line 23) where the cushioning commenced on the return or exhaust stroke of the piston. The back pressure at this point is at the minimum. From this point to the end of the stroke of the piston the back pressure steam contained in the cylinder between the piston and the same at the end of its stroke, and in the clear-

ance and steam passage, is compressed into the space of the clearance and steam passage, thus forming the cushioning. Of course, the weight of steam drawn from the boilers per stroke of piston is just so much the less by the weight of steam thus "cushioned."

Line 23 shows the fraction completed of the exhaust or return stroke of the piston of the small cylinder when the exhaust port is closed and the "cushioning" of the back pressure commences.

Line 24 contains the mean indicated pressure on the piston of the small cylinder; and line 25 contains the mean net pressure on the same, in pounds per square inch. The net pressure is the indicated pressure less the pressure required to work the unloaded engine. This latter pressure is taken at 3.60 pounds per square inch of the piston of the small cylinder.

Line 26 contains the mean total pressure on the piston of the small cylinder, exclusive of the cushioning, in pounds per square inch above zero, obtained in the following manner: The mean back pressure against the piston, exclusive of cushioning, in pounds per square inch above zero, is reduced in the proportion of 1 or unity to the fraction on line 23, and the quantity thus obtained is added to the indicated pressure on line 24. The quantity on line 26 is the entire resistance per square inch of the piston of the small cylinder that is overcome by the steam drawn from the boiler.

Line 27 contains the mean pressure of the expanding steam alone in the small cylinder, in pounds per square inch above zero; that is to say, the mean pressure of the steam after the closing of the cut off valve of the small cylinder.

Steam Pressures in the Two Large Cylinders per Indicator.— Lines 28 to 37, both inclusive, contain the various steam pressures in the two large cylinders, as given by the means taken from all the indicator diagrams. It will be understood that the large cylinders, though mechanically two, are in effect only one, and should be considered in all respects as one cylinder of double capacity of each.

Lines 28, 29 and 30 contain respectively the steam pressures on the pistons of the large cylinders at the commencement of

their stroke, at the point of cutting off the steam, and at the end of their stroke, in pounds per square inch above zero.

Line 31 contains the mean back pressure, including cushioning, against the pistons of the large cylinders during their stroke, in pounds per square inch above zero.

Line 32 contains the back pressure in pounds per square inch above zero against the pistons of the large cylinders at the point (line 33) where the cushioning commenced on the return or exhaust strokes of the pistons. The back pressure at this point is at the minimum. From this point to the end of the stroke of the pistons the back pressure steam contained in the large cylinders between their pistons and the same at the end of their stroke, and in the clearances and steam passages at one end of the cylinders, is compressed into the space of these clearances and steam passages, thus forming the "cushioning." Of course, the weight of steam drawn from the receiver per stroke of pistons is just so much the less by the weight of steam thus "cushioned."

Line 33 shows the fraction completed of the exhaust or return stroke of the pistons of the large cylinders when their exhaust ports are closed and the "cushioning" of the back pressure commences.

Line 34 contains the mean indicated pressure on the pistons of the large cylinders; and line 35 contains the mean net pressure on the same, in pounds per square inch. The net pressure is the indicated pressure less the pressure required to work the engine, *per se*, or unloaded. The latter pressure is taken at 0.90 pound per square inch of the pistons of the two large cylinders.

Line 36 contains the mean total pressure in pounds, per square inch above zero, exclusive of the cushioning, on the area that remains of the aggregate area of the pistons of the two large cylinders after deducting the area of the piston of the small cylinder. This pressure is the entire resistance, per square inch of the above annular area of the pistons of the large cylinders that is overcome by the steam drawn from the receiver, and is obtained as follows: The mean back pressure against the pistons, exclusive of cushioning, in pounds per square inch above zero, is reduced in the proportion of 1 or unity to the fraction on line 33,

and the quantity thus obtained is added to the indicated pressure on line 34.

Line 37 contains the mean pressure of the expanding steam in the large cylinders in pounds per square inch above zero. All the steam used in the large cylinders is expanding steam from the beginning to the end of the stroke of their pistons. The cut off valve placed on the large cylinders does not increase or influence the ratio of the expansion of the steam for the entire compound engine, in which respect the point in the stroke of the pistons of the large cylinders at which the cut off valve is arranged to close is immaterial. The use of that valve is to increase or decrease, according as it closes earlier or later, the back pressure against the piston of the small cylinder, and to work the steam expansively which is evaporated in the small cylinder during the exhaust stroke of the piston from the water of liquefaction deposited therein during the steam stroke. This re-evaporated steam is used in the large cylinders with whatever measure of expansion is due to the point at which their cut off valves close.

Horses-Power.—Lines 38 and 39 contain respectively the indicated horses-power developed in the small cylinder and in the two large cylinders of the engine. They are calculated for the areas of the pistons of the respective cylinders, for the speed of piston due to the quantities on line 14, and for the pressures on lines 24 and 34. Line 40 contains the sum of the quantities on lines 38 and 39, and gives the aggregate indicated horses-power developed by the engine.

Lines 41 and 42 contain, respectively, the net horses-power developed in the small cylinder and in the two large cylinders of the engines. They are calculated for the areas of the pistons of the respective cylinders, for the speed of piston due to the quantities on line 14, and for the pressures on lines 25 and 35.

Line 43 contains the sum of the quantities on lines 41 and 42, and gives the aggregate net horses-power developed by the engine.

Line 44 contains the total horses-power developed in the small cylinder, calculated for the area of its piston, for the speed of its piston due to the quantities on line 14, and for the pressure on line 26, which pressure it will be observed is above zero.

Line 45 contains the total horses-power developed in the two large cylinders, calculated for the speed of their pistons due to the quantities on line 14, for the pressures on line 36, and for what remains of the aggregate areas of the pistons of the two large cylinders after the area of the piston of the small cylinder has been deducted. The deduction of the area of the piston of the small cylinder is rendered necessary by the fact that the total pressures upon it (line 26) has been taken above zero and consequently includes the total pressure upon the pistons of the large cylinders for an area equal to that of the piston of the small cylinder; therefore, the total power developed in the two large cylinders will be only what is due to what remains of their aggregate area after deduction of the area of the piston of the small cylinder.

Line 46 contains the sum of the quantities on lines 44 and 45, and gives the aggregate total horses-power developed by the engine.

Line 47 contains the total horses-power developed by the expanding steam alone in the small cylinder, calculated for the area of its piston, for the speed of its piston due to the quantities on line 14, and for the pressure on line 27 reduced in the proportion of 1 or unity to the fraction on line 9.

Line 48 contains the total horses-power developed by the expanding steam alone in the two large cylinders calculated for the speed of their pistons due to the quantities on line 14 for the pressures on line 37 and for what remains of the aggregate areas of the pistons of the two large cylinders after the area of the piston of the small cylinder has been deducted.

Line 49 contains the aggregate total horses-power developed by the expanding steam alone in all the cylinders, and gives the sum of the quantities on lines 47 and 48.

Weight of Steam Accounted for per Hour by the Indicator.—Line 50 gives the number of pounds of steam present per hour in that state in the small cylinder at the point of cutting off the steam (line 9), calculated from the pressure (line 19) there. The calculation is made for the number of cubic feet of space displacement of the piston per hour up to the point of cutting off plus the corresponding spaces in the clearance and steam passage and for the

weight of steam per cubic foot due to the pressure on line 19. From the quantity thus obtained is deducted the product of the number of cubic feet in the space displacement of the piston per hour from the point (line 23) at which the cushioning commenced to the end of the stroke, plus the corresponding spaces in the clearance and steam passage multiplied by the weight of the back pressure steam per cubic foot due to the pressure on line 22.

Line 51 gives the number of pounds of steam present per hour in that state in the small cylinder at the end of the stroke of its piston calculated from the pressure (line 20) there. The calculation is made in precisely the same manner as described for the quantities on line 50, substituting the space displacement of the piston per stroke for its space displacement to the point of cutting off.

Line 52 contains the number of pounds of steam liquefied per hour in the small cylinder to furnish the heat transmuted into the total horses-power developed in that cylinder by the expanded steam alone after the closing of the cut off valve. In making this calculation $789\frac{1}{4}$ foot-pounds of work are taken as the equivalent of one Fahrenheit unit of heat, and one horse power is taken as 33,000 foot-pounds of work done per minute, or as equivalent to $\frac{33{,}000}{789\frac{1}{4}} = 41.812$ Fahrenheit units of heat; consequently this latter number multiplied by 60 minutes and by the number of horses-power (line 47) developed by the expanding steam alone, gives the number of Fahrenheit units of heat transmuted per hour into that power, and this number divided by the latent heat of the mean pressure of the expanding steam alone (line 27) gives the quantity on line 52.

Line 53 contains the sum of the quantities on the two immediately preceding lines. This sum is the number of pounds of steam accounted for per hour by the indicator in the small cylinder at the end of the stroke of its piston.

Line 54 gives the number of pounds of steam present per hour in that state in the two large cylinders at the end of the stroke of their pistons, calculated from the pressure (line 30) there. The

calculation is made in precisely the same manner as described for the quantities on line 51.

Line 55 contains the number of pounds of steam liquefied per hour in the small and large cylinders and in the receiver between them, to furnish the heat transmuted into the total horses-power developed in the small and large cylinders by the expanded steam alone after the closing of the cut off valve. The calculation is made for the two large cylinders in precisely the same manner as described for the small cylinder (line 52), the horses-power being those on line 48, and the mean pressures of the expanding steam being those on line 37. These results being added to the quantities on line 52, make those on line 55.

Line 56 contains the sum of the quantities on the two immediately preceding lines (54 and 55). The sum is the number of pounds of steam accounted for per hour by the indicator in the two large cylinders at the end of the stroke of their pistons. This quantity furnishes the *minimum* limit of pounds weight of steam consumed per hour. The consumption might be more but could not be less. An addition of one-eighth of this quantity to the quantity itself, would in the case of the maximum power trial, probably give a very close approximation to the true consumption of steam per hour.

Ratios of the Powers.—Lines 57, 58 and 59 contain, respectively, the per centum which the quantities on lines 40, 43 and 49 are of the quantities on line 46. They show the fraction of the total horses-power (line 46) developed by the engine, calculated for the mean pressure upon the pistons down to the zero line, which is utilized as indicated horses-power (line 40), as net horses-power (line 43), and as power developed by the expansion of the steam (line 49).

Cylinder Pressures Reduced to the Two Large Cylinders Alone.—For purposes of comparison, and for future use, it is necessary to have a single expression for the different *mean* pressures on the piston of the small cylinder and on the pistons of the two large cylinders considered as one of double area. This is obtained by reducing the mean indicated and net pressures on the piston of the small cylinder, in the ratio of the area of that piston to the

aggregate area of the pistons of the two large cylinders, and adding the result to the corresponding mean pressures on the pistons of those cylinders. For the mean total pressure on the pistons of the large cylinders, the total horses-power (line 46) developed by the engine is multiplied by 33,000 and the product divided by the product of the aggregate areas in square inches of the pistons of the large cylinders into their speed per minute deduced from the quantities on line 14. In this manner there have been found the quantities on lines 60, 61 and 62, which are, respectively, the indicated, net and total pressures in pounds per square inch which would, if exerted upon the areas of the pistons of the large cylinders alone, when moving at the speed due to the quantities on line 14, have produced the indicated, net and total horses-power on lines 40, 43 and 47, respectively.

The quantities on line 63 are obtained by subtracting the quantities on line 60 from those on line 62, and are the back pressures against the pistons of the large cylinders due not only to the imperfect condensation of the exhaust steam in the condenser, but additionally to the difference between the back pressure exclusive of cushioning in pounds per square inch above zero against the piston of the small cylinder, and the mean pressure on the pistons of the large cylinders in pounds per square inch above zero, from the initial pressure (line 28) to the pressure at the point of cutting off (line 29).

Rate of Combustion.—Line 64 contains the number of pounds of commercial anthracite consumed per hour during the experiment at sea of 12 hours and 27 minutes duration. The refuse was not obtained, but probably did not exceed one-eighth, as the anthracite was burned at an excessively slow rate, and without cleaning of fires.

Line 65 gives the rate of combustion in pounds of anthracite consumed per hour per square foot of grate surface, obtained by dividing the quantity on line 64 by 149.

Line 66 gives the rate of combustion in pounds of anthracite consumed per hour per square foot of water heating surface calculated for the inside diameter of the boiler tubes, obtained by dividing the quantity on line 64 by 3,038.4.

Line 67 gives the rate of combustion in pounds of anthracite consumed per hour per square foot of water heating surface calculated for the outside diameter of the boiler tubes, obtained by dividing the quantity on line 64 by 3,220.

Cost of the Powers.—The quantities on lines 68, 69 and 70, are respectively the quotients of the division of the quantity on line 64 by those on lines 40, 43 and 46, and give the cost of the indicated, net and total horses-power developed by the engine, in pounds of anthracite consumed per hour. The anthracite was burned as slowly as possible, and keep an ignited bed over the entire grate surface.

Note.—The "cushioned" steam in all the preceding calculations has been treated as simply a foreign body in the cylinders, the results of power being calculated entirely for the expenditure of steam drawn from the boilers and exhausted into the condenser.

REMARKS.

The foregoing exact data, and the calculations based on them, add that much to our experimental knowledge in steam engineering, and assist in furnishing the indisputable facts necessary to its successful practice. Especially do the experiments show the power which can be obtained from the machinery employed and from the kind of fuel consumed, the economy as regards the propulsion of the vessel with which that power was applied by the screw, and the speed which such machinery could give to such a vessel as the *Yosemite* under the experimental conditions.

The data and results of these trials allow an analysis to be made of the power exerted, showing what proportion of it was expended in overcoming the various resistances incidental to the propulsion of the hull; and in what proportion the ratio of the power to speed of vessel increased for an increase of speed from the low to the high experimental speed.

Only a portion of the indicated horses-power developed by the engine, and that, too, a very variable portion, according to circumstances and conditions, is applied to the propulsion of the hull.

There is first to be deducted the power required to work the engine, *per se*, or unloaded, at the experimental speed, which is obtainable by disconnecting the screw and taking indicator diagrams from the cylinders when their pistons make the experimental number of double strokes per minute. The *pressure* shown upon the indicator diagrams thus taken, will be found to be practically the same for all speeds of piston from the lowest to the highest, consequently, the *power* required to work the engine, *per se*, will be directly proportional to the number of double strokes made in a given time by its pistons. In the case of a compound engine working unloaded, the pressure upon the piston of the small cylinder will be found by the indicator to be exactly as many times greater than the pressure upon the piston of the large cylinder, as the area of the piston of the large cylinder is greater than the area of the piston of the small cylinder, the pistons of both cylinders having equal length of stroke. This proportion necessarily results from the fact that exactly the weight of steam used in the large cylinder has first to be used in the small one, so that the pressures in the two cylinders must be in the inverse ratio of the space displacements of their pistons per stroke. The aggregate power thus obtained, however, distributed between the small and large cylinders, is the power required to work the engine, *per se*, and it is of little consequence how the distribution is taken provided the aggregate remains the same.

The small and large cylinders of a compound engine do not compose two simple engines with cylinders of unequal capacity and with independent functions. The small and the large cylinder of the compound engine have interacting functions and are indivisible, the two constituting one engine, whereas each cylinder in the case of a simple engine is a complete engine.

After deduction is made of the power required to work the engine, *per se*, from the indicated horses-power (for until the resistance of the unloaded moving organs of the engine are overcome there can be no development of power) the remainder is the net horses-power and is the power applied to the crank pins. This is the external or commercial power developed by the engine

additional to the internal power expended in working the engine, *per se*.

Now, there is a friction on the journals and bearing surfaces exterior to the cylinders of all the organs of the engine in motion, due solely to the resistance of the load, and consequently proportional to the net horses-power which represent the load. The greater the resistance of the load the greater is the pressure under which these journals and bearing surfaces move. This friction of the load is taken at $7\frac{1}{2}$ per centum of it—an experimental determination for well lubricated journals. This friction of the load must be deducted from the net horses-power.

The helicoidal surfaces of the screw propeller moving in their helical paths, experience a resistance from the water of the same kind which the wetted surface of the hull experiences, and capable of calculation in the same manner. This resistance is taken to be 0.45 pound avoirdupois per square foot of helicoidal surface moving in its helical path with a velocity of 10 feet per second, and for other velocities this 0.45 pound is modified in the ratio of their squares to the square of 10. When the dimensions of the screw are known, and the number of revolutions it makes per minute, the horses-power expended in overcoming the surface resistance of its blades can be calculated by means of the above data. These horses-power must be deducted from what remains of the net horses-power after subtraction of the horses-power absorbed by the friction of the load, and the remainder are the horses-power expended in the slip of the screw and in the propulsion of the vessel, and are divided in the ratio of the speeds of the two, the pressure exercised by the screw forward in propelling the vessel and backward upon the receding mass of water constituting the slip of the screw being the same. Hence, if the aforesaid remainder of power be multiplied by the speed of the slip expressed in fractions of the axial speed of the screw, the product will be the horses-power expended in the slip, which, being subtracted from the above remainder, leaves the residue as the horses-power expended in the propulsion of the vessel.

The necessary calculations having been made in accordance

with the foregoing assumptions, give the following for the distribution of the indicated horses-power developed by the engine when the vessel was at the speed of 10.125 geographical miles per hour:

	Horses-power	Per centum of the net horses power.
Indicated horses-power developed by the engine.....	291 658	
Horses power expended in working the engine, *per se*...	48.888	
Net horses-power applied to the crank pins.....	242.770	100 00
Horses power absorbed by the friction of the load.....	18 208	7.50
Horses power expended in overcoming the resistance of the water to the screw surface.....	16 565	6.82
Horses-power expended in the slip of the screw.....	28.274	11.65
Horses-power expended in the propulsion of the vessel	179.723	74.03
Totals.....	242.770	100.00

The thrust of the screw, as it would have been measured by a dynamometer directly applied to the shaft during the above performance, calculated from the data given therein and in the distribution of the power, is as follows:

The horses-power expended in the propulsion of the vessel according to the distribution of the power, being 179.723 is equal to (179.723 × 33,000 =) 5,930,864.346 foot-pounds of work per minute, and the speed of the vessel being 10.125 geographical miles per hour, is equal to $\left(\frac{10.125 \times 6{,}086}{60} = \right)$ 1,027.0125 feet per minute; hence the resistance of the vessel at that speed, or its equivalent, the thrust of the screw, is $\left(\frac{5{,}930{,}864.346}{1{,}027.0125} = \right)$ 5,774.871 pounds.

The distribution of the power given immediately below, is for the maximum speed of 15.6 geographical miles per hour; and the quantities are calculated in exactly the same manner as previously described for the speed of 10.125 geographical miles per hour.

	Horses-power.	Per centum of the net horses-power.
Indicated horses-power developed by the engine.....	1,403.744	
Horses-power expended in working the engine, *per se*...	80.755	
Net horses-power applied to the crank pins.....	1,322.989	100.00
Horses-power absorbed by the friction of the load.....	99.224	7.50
Horses-power expended in overcoming the resistance of the water to the screw surface.....	74.130	5.60
Horses-power expended in the slip of the screw.....	233.814	17.67
Horses-power expended in the propulsion of the vessel..	915.821	69.23
Totals.....	1,322.989	100.00

The thrust of the screw, as it would have been measured by a dynamometer directly applied to the shaft during the above performance, calculated from the data given therein and in the distribution of the power, is as follows:

The horses-power expended in the propulsion of the vessel according to the distribution of the power, being 915.821, is equal to ($915.821 \times 33{,}000 =$) 30,222,095.97 foot-pounds of work per minute; and the speed of the vessel being 15.6 geographical miles per hour, is equal to $\left(\frac{15.6 \times 6.086}{60} =\right)$ 1,582.36 feet per minute; hence the resistance of the vessel at that speed, or its equivalent, the thrust of the screw, is $\left(\frac{30{,}222{,}095.97}{1{,}582.36}\right) = 19{,}099.381$ pounds.

If the resistance of the hull had increased in the ratio of the square of its speed from the speed of 10.125 to that of 15.6 geographical miles per hour, its resistance at the latter speed would have been ($5{,}774.871 \times 1.540741^2 =$) 13,714.636 pounds; its actual resistance being 19,099.381 pounds, was $\left(\frac{19{,}099.381 - 13{,}714.636 \times 100}{13{,}714.636} =\right)$ 39.263 per centum greater than was due to this ratio.

The resistance of the hull in function of speed to power, in pass-

ing from the speed 10.125 knots to the speed 15.6 knots, increased in the 2.654 power of the speed.

The resistance of a hull of given dimensions is due to the form of its immersed solid, and to the water friction of its wetted surface. Within certain limits of speed, the hull will retain its *trim* and its mean draught of water; its resistance consequently varying sensibly as the square of its speed; but when that limit is passed, the hull will *squat*, that is, its bow will rise and its stern will fall relatively to their previous positions; the vessel's mean draught of water will increase with corresponding increase of greatest immersed transverse section, displacement and wetted surface; the form of the immersed solid will also change relatively to the water level, and its resistance will increase in a higher ratio than the square of speed; in fact, abstractly, for each speed above the squatting limit, there will be a differently shaped immersed solid relatively to the water level, each succeeding solid having a greater resistance than the preceding one, supposing them all to be tried at the same speed, which, though not possible experimentally, can be conceived. Above the squatting limit of speed, so many different speeds, so many different models, each worse than any of its predecessors. As the speed of the vessel increases above that of the squatting limit, the correspondingly increasing mass of water at the bow raised above the normal level, lifts the bow, and the correspondingly decreasing mass of water supporting the stern allows the stern to fall, both causes operating to change the vessel's trim and to increase its resistance above the ratio of the square of the speed. The amount of this increase can only be ascertained by the process herein adopted for the particular cases of *Yosemite*, of analyzing the indicated horses-power developed by the engine for the different speeds, and calculating the exact portion of it applied to the propulsion of the vessel. The usual method of comparing the speeds of the vessel with the entire indicated horses-power developed by the engine will give very erroneous results, misleading and of no value in any particular.

Taking, for illustration, the cases of the *Yosemite*: the indicated horses-power for the speeds of 10.125 and 15.6 knots,

compare as 1 to 4.813, while the horses-power actually applied to propelling the vessel compare as 1 to 5.096. The cubes of the speeds compare as 1 to 3.659. And $\frac{4.813}{3.659} = 1.31536$, while $\frac{5.096}{3.659} = 1.39263$, showing that, if the indicated horses-power were taken for the comparison, the increased resistance at the higher speed above the normal ratio would be 31.536 per centum, and if the horses-power actually applied to the propulsion were taken the increased resistance would be 39.263 per centum.

During the maximum speed trial of 15.6 geographical miles per hour, the speed of the screw was 19.583 geographical miles per hour, the slip of the screw being, consequently, 3.983 geographical miles per hour, or 20.338 per centum. Now, the slip of the screw during the 10.125 geographical miles per hour trial was 14.593 per centum, and had its per centage remained the same during the 15.6 geographical miles per hour trial, the speed slip of the screw would have been ($19.582764 \times 0.14593562 =$) 2.857823 geographical miles per hour. Under these conditions, the increased resistance of the hull above what was due to the ratio of the square of the speed, should compare as the speed slips of the screw in the two cases, namely, as 3.982764 to 2.857823; the former quantity is $\left(\frac{3.982764 - 2.857823 \times 100}{2.857823} =\right)$ 39.364 per centum greater than the latter. The previous determination of the increased resistance made from the distributions of the power, gave this percentage, 39.263, which is just the same.

The only weights on board the *Yosemite* during these experiments were those of the personnel embarked, their effects, furniture, galley, provisions and water for a few days, anchors and chains, and sufficient coal to make the trials. Of course, if the vessel had to be used for any naval or mercantile purpose, the necessary weights to be added would very largely increase the draught of water and decrease the speed. These facts, however, do not lessen the value of the experimental engineering results, which were obtained with the greatest accuracy.

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE WITH THE *YOSEMITE* AT MAXIMUM SPEED DURING FOUR CONSECUTIVE RUNS OVER A MEASURED GEOGRAPHICAL MILE IN NARRAGANSETT BAY, RHODE ISLAND, BURNING ANTHRACITE WITH BLOWER DELIVERING AIR INTO CLOSED ASHPITS: AND DURING 12 HOURS AND 27 MINUTES CONSECUTIVELY AT SEA BETWEEN NEWPORT AND PORTSMOUTH, NEW HAMPSHIRE, BURNING ANTHRACITE AT THE SLOWEST PRACTICABLE RATE WITH NATURAL DRAFT. IN BOTH CASES THE WATER WAS PERFECTLY SMOOTH AND THE AIR NEARLY CALM.

No. of line		Mean of four runs over a measured knot at maximum speed, burning anthracite with blower.	Mean of a trial of 12 hours 27 minutes, burning anthracite with natural draft at slowest possible rate.
	Vessel		
	Date of the experiments	July, 1884.	July 23–24, 1884.
1	Vessel's draught of water forward, in feet and inches from bottom of keel	9–10	9– 8
2	Vessel's draught of water aft, in feet and inches from bottom of keel	11–10	11–10
3	Vessel's draught of water amidship, in feet and inches from bottom of keel	10–10	10– 9
4	Vessel's greatest immersed transverse section, in square feet	156.62	154.62
5	Vessel's displacement, in tons of 2,240 pounds	444.702	437.708
6	Vessel's external immersed or wetted surface, in square feet, including keel and rudder	4,800.35	4,770.18
	Engine.		
7	Steam pressure in boilers in pounds per square inch above the atmosphere	108.00	80.87
8	Steam pressure in receiver in pounds per square inch above the atmosphere	.....	8.18
9	Fraction completed of the stroke of the piston of the small cylinder when the steam was cut off	0.632	0.111
10	Fraction completed of the stroke of the pistons of the large cylinders when the steam was cut off	0.632	0.111
11	Number of times the steam was expanded	6.027	25.352
12	Vacuum in the condenser in inches of mercury	.....	25.75
13	Pressure in the condenser in pounds per square inch above zero	.....	2.05
14	Number of double strokes made per minute by the pistons of the engine	107.37	65.00
	Speed.		
15	Speed of the vessel per hour in statute miles of 5,280 feet	17.981	11.671
16	Speed of the vessel per hour in geographical miles of 6,086 feet	15.600	10.125
17	Slip of the screw in per centum of its speed (18.50 feet pitch)	20.338	14.594
	Steam Pressure in the Small Cylinder per Indicator.		
18	Pressure on the piston of the small cylinder at commencement of its stroke in pounds per square inch above zero	111.54	86.73
19	Pressure on the piston of the small cylinder at point of cutting off the steam in pounds per square inch above zero	93.20	82.89
20	Pressure on the piston of the small cylinder at the end of its stroke in pounds per square inch above zero	64.94	21.39

No. of line		Mean of four runs over a measured knot at maximum speed, burning anthracite with blower.	Mean of a trial of 12 hours 27 minutes, burning anthracite with natural draft at slowest possible rate.
	Steam Pressure in the Small Cylinder per Indicator.		
21	Mean back pressure against piston of small cylinder during its stroke (including cushioning) in pounds per sq. in. above zero	28.69	21.27
22	Back pressure against piston of small cylinder at the point where the cushioning of the steam commences in pounds per square inch above zero	27.59	20.17
23	Fraction completed of the return stroke of the piston of the small cylinder when the back pressure steam was cushioned	0.896	0.774
24	Indicated pressure on the piston of the small cylinder in pounds per square inch	64.97	21.87
25	Net pressure on the piston of the small cylinder in pounds per square inch	61.37	18.27
26	Total pressure on the piston of the small cylinder (exclusive of the cushioning) in pounds per square inch above zero	90.06	37.75
27	Mean pressure of the expanding steam alone, in the small cylinder, in pounds per square inch above zero	75.00	33.50
	Steam Pressures in the Large Cylinders per Indicator.		
28	Pressure on the pistons of the large cylinders at commencemeut of their stroke in pounds per square inch above zero	27.25	20.15
29	Pressure on the pistons of the large cylinders at point of cutting off the steam in pounds per square inch above zero	21 68	17.50
30	Pressure on the pistons of the large cylinders at the end of their stroke in pounds per square inch above zero	14 37	4.81
31	Mean back pressure against the pistons of the large cylinders during their stroke (including cushioning) in pounds per square inch above zero	7.00	4.17
32	Back pressure against the pistons of the large cylinders at the point where the cushioning of the steam commences, in pounds per square inch above zero	6.06	3.82
33	Fraction completed of the return stroke of the pistons of the large cylinders when the back pressure steam was cushioned	0.896	0 774
34	Indicated pressure on the pistons of the large cylinders in pounds per square inch	15.04	5.27
35	Net pressure on the pistons of the large cylinders in pounds per square inch'	14 14	4.37
36	Total pressure in pounds per square inch above zero, exclusive of the cushioning, on the area that remains of the aggregate pistons of the large cylinders after deducting the area of the piston of the small cylinder	20.86	8.75
37	Mean pressure of the expanding steam alone, in the large cylinders, in pounds per square inch above zero	22.04	9.44
	Horses-power.		
38	Indicated horses-power developed in the small cylinder	732.604	149 292
39	Indicated horses-power developed in the large cylinders	671.140	142.366
40	Aggregate indicated horses-power developed by the engine	1,403.744	291.658
41	Net horses-power developed in the small cylinder	692.010	124 717
42	Net horses-power developed in the large cylinders	610.979	118.053
43	Aggregate net horses-power developed by the engine	1,322.989	242.770
44	Total horses-power developed in the small cylinder	1,015 520	257.694
45	Total horses-power developed in the large cylinders, by the area that remains of their pistons afrer deducting from them the area of the piston of the small cylinder	695 632	176.646
46	Aggregate total horses-power developed by the engine	1,711.152	434.340
47	Total horses-power developed by the expanded steam alone in the small cylinder	311.219	186.147
48	Total horses-power developed by the expanded steam alone in the large cylinders	695.632	176 646
49	Aggregate total horses-power developed by the expanded steam in all the cylinders	1,006 850	362 793

	Weight of Steam Accounted for per Hour by the Indicator.		
50	Pounds of steam present per hour in the small cylinder at point of cutting off the steam, calculated from the pressure there	22,030.112	1,974.192
51	Pounds of steam present per hour in the small cylinder at end of the stroke of its piston, calculated from the pressure there	24,376.753	4,048.657
52	Pounds of steam liquefied per hour in the small cylinder to furnish the heat transmuted into the total horses-power developed in that cylinder by the expanded steam alone after the closing of the cut off valve	869.854	500.018
53	Sum of the two immediately preceding quantities	25,246.607	4,548.675
54	Pounds of steam present per hour in the large cylinders at the end of the stroke of their pistons, calculated from the pressure there	22,776.738	4,073.301
55	Pounds of steam liquefied per hour in the small and large cylinders and in the receiver to furnish the heat transmuted into the total horses-power developed in the small and large cylinders by the expanded steam alone after the closing of the cut off valve in the small cylinder	2,705.757	951.796
56	Sum of the two immediately preceding quantities	25,482.495	5,025.097
	Ratio of the Powers.		
57	Per centum which the aggregate indicated horses-power are of the aggregate total horses-power developed by the engine	82.035	60.243
58	Per centum which the aggregate net horses-power are of the aggregate total horses power developed by the engine	77.316	55.894
59	Per centum which the aggregate total horses-power developed by the expanding steam alone are of the total horses-power developed by the engine	58.841	82.527
	Cylinder Pressures Reduced to the Two Large Cylinders alone.		
60	Indicated pressure in pounds per square inch that would be on the pistons of the large cylinders were the indicated pressure on the piston of the small cylinder divided by the ratio of the area of the small to the aggregate areas of the large cylinders, and the quotient added to the experimental indicated pressure on the pistons of the large cylinders	31.457	10.796
61	Net pressure in pounds per square inch that would be on the pistons of the large cylinders, similarly calculated to the immediately above	29.648	8.987
62	Total pressure in pounds per square inch above zero that would be on the pistons of the large cylinders corresponding to the total horses-power developed by the engine	38.346	16.078
63	Back pressure in pounds per square inch above zero that would be against the pistons of the large cylinders, similarly calculated to the above	6.889	5.282
	Rate of Combustion.		
64	Pounds of anthracite consumed per hour (mean for 12 hours and 27 minutes consecutively)	.....	563.000
65	Pounds of anthracite consumed per hour per square foot of grate surface	.....	3.779
66	Pounds of anthracite consumed per hour per square foot of water heating surface, calculated for inside diameter of tubes	.....	0.185
67	Pounds of anthracite consumed per hour per square foot of water heating surface, calculated for outside diameter of tubes	.....	0.175
	Cost of the Powers.		
68	Pounds of anthracite consumed per hour per indicated horse-power	.....	1.930
69	Pounds of anthracite consumed per hour per net horse-power	.....	2.319
70	Pounds of anthracite consumed per hour per total horse-power	.....	1.296

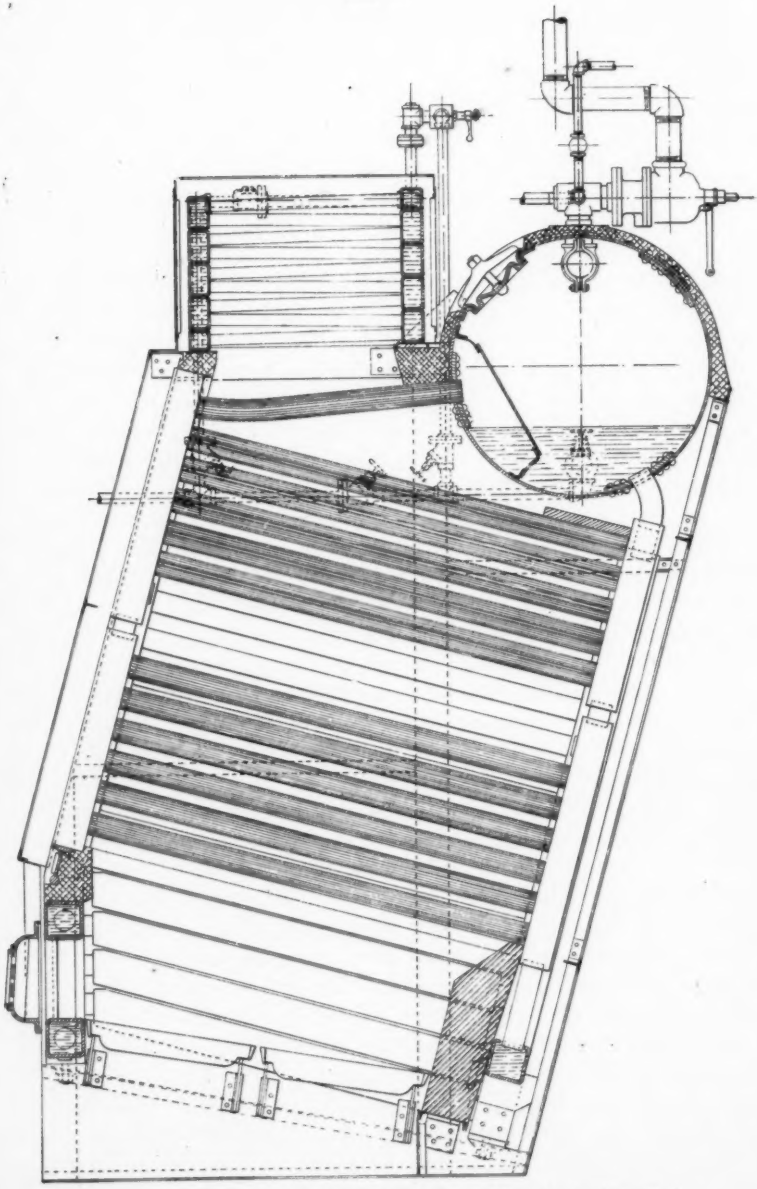
TEST OF A BABCOCK AND WILCOX BOILER TO DETERMINE ITS EVAPORATIVE EFFICIENCY.

The test herein recorded was made on a shop boiler at the works of the Babcock and Wilcox Company, at Elizabethport, New Jersey, and was conducted under instructions from the Bureau of Steam Engineering of the Navy Department by a Board of naval engineers composed of Chief Engineers H. S. Ross and George Cowie, Jr., and Passed Assistant Engineer F. H. Bailey, U. S. Navy, from whose report the data have been taken.

The object of the test being to determine the evaporative efficiency of the boiler at a high rate of combustion, and to ascertain whether such a rate as is sometimes reached on the trial trips of naval vessels could be maintained for a considerable length of time without injury to the boiler, it was arranged between the Board and the firm submitting the boiler for test that the rate of combustion should be maintained at 50 pounds per square foot of grate surface per hour, and that the test should continue for twenty-four consecutive hours. Incidentally, it was desired to obtain figures which might be used in making a comparison with tests of other water tube boilers which had been tested by the Bureau of Steam Engineering, and for this reason the safety valves were set to blow off at 160 pounds per square inch above the atmosphere.

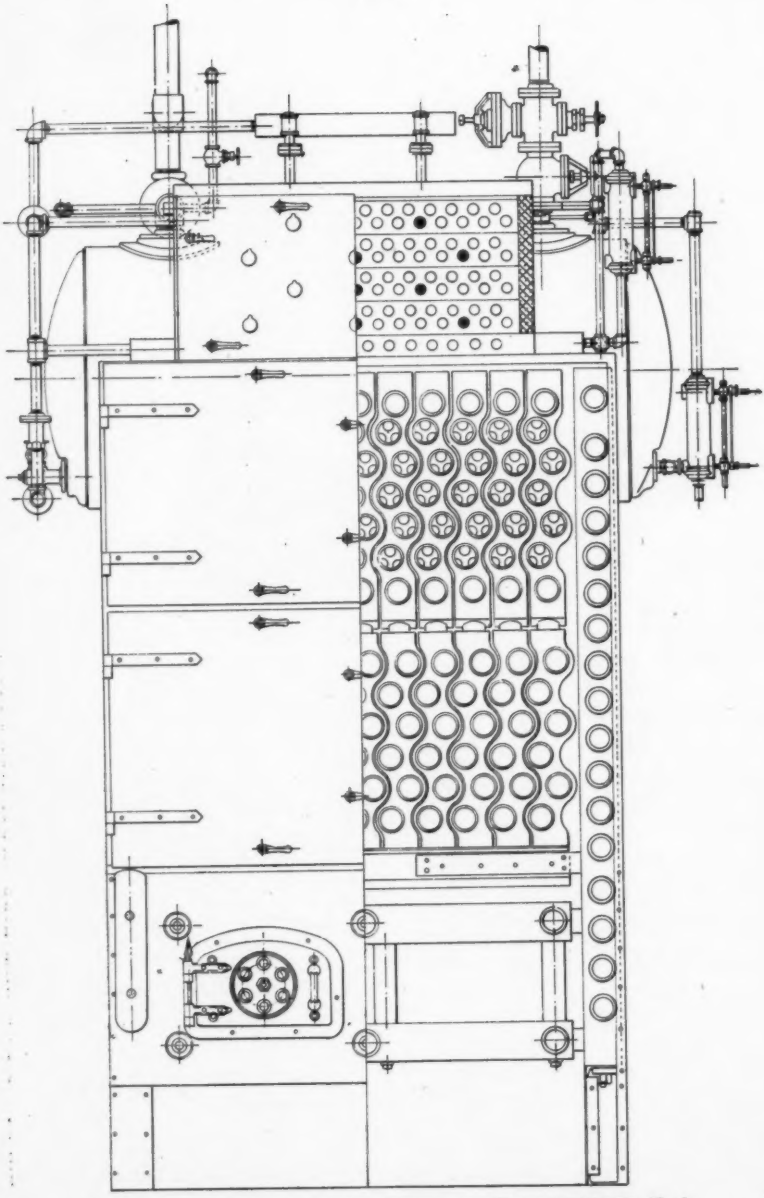
The test commenced at 12·06 P. M. on the 22d of April, 1895, and ended at the same time on the following day. The usual appliances for accurately measuring coal and feed water were used, and also a Barrus throttling and an ordinary barrel calorimeter for testing the dryness of the steam. All the instruments used were carefully tested and found to be correct. They comprised two pressure gauges, one of which was a test gauge from the New York navy yard, and both of which were attached to the top of the steam drum; a barrel calorimeter with a propeller

FIG. I.



BABCOCK & WILCOX BOILER. TESTED AT ELIZABETHPORT, N. J.

FIG. 1.



BABCOCK & WILCOX BOILER. TESTED AT ELIZABETHPORT, N. J.

agitator and a thermometer reading to $\frac{1}{10}$ of a degree Fahrenheit, the steam pipe being heavily coated with non-conducting material, and the attached rubber hose provided with a rosette having $\frac{1}{8}$-inch holes; a Barrus throttling calorimeter, located on top of the steam drum, and taking steam through a $\frac{3}{8}$-inch pipe from the center of the main steam pipe at its discharge from the boiler; three air pressure gauges to measure the pressure of air in inches of water, one connected to the base of the smoke pipe, one to the furnace, and the third to the ash pit, each provided with a vernier reading to $\frac{1}{100}$ of an inch; a Shaeffer and Budenberg metallic expansion pyrometer which was inserted across the base of the smoke pipe; and an Aneroid barometer with attached thermometer. In the base of the smoke pipe, and 8 inches from the side of it, were also two pieces each of lead, zinc and antimony. The platform scales for weighing the coal were new, but were difficult to graduate nearer than one-quarter of a pound, on account of the vibration of the blower engine, near which they were placed, interfering with accurate balancing. The quantity of coal weighed each time was 200 pounds. A portion of the steam generated was reduced to a pressure of 100 pounds and used for running the shop engine, the remainder being blown into the atmosphere by means of a pipe passing from the safety valves up through the roof of the building.

The boiler, which is shown in the accompanying Figure 1, consists essentially of two nests of tubes, one above the other, inclined at an angle of 15 degrees to the horizontal, the ends of the tubes being expanded in sinuous headers at the front and back of the boiler, the front headers connecting with the steam space of a drum placed across the tubes and at the back of the boiler, and the back headers with the water space of this drum. The tubes of the lower nest are 4 inches in diameter, and those of the upper, 2 inches, the latter in groups of three whose ends are accessible through a single opening in the headers; the ends of all tubes are expanded. The headers are forged of wrought iron with ends welded in, and the two tiers of headers at front and back connected by short expanded nipples. The front headers are connected to the steam drum by 4-inch tubes, and

the back ones by short bent nipples, which are expanded in drum and header, there being no screwed joints in the boiler.

On each side of the furnace there are four water boxes 6 inches square forming the sides of the furnace, and above these, twelve 4-inch tubes on each side forming the sides of the boiler. These tubes are covered with a non-conducting cement and cased with sheet iron.

Access to the ends of the tubes is had through openings in the headers. These openings are closed by plates making a ground joint on the outside of the header, the dog being inside and of such form that it quite fills the opening, so that if a stud breaks the leakage will be slight.

Above the upper nest of tubes, and in the base of the smoke pipe, there is a feed water heater consisting of ten horizontally placed water manifolds, five at the front and five at the back end, one above the other, connected by short lengths of pipe, and so arranged that the feed water entering at the bottom passes in a zig-zag course through the manifolds and tubes to the outlet at the top to the water drum. From this outlet, return pipes on each side with check valves in them lead to the lower water manifold, so that in the event of the feed being shut off, circulation will be maintained in the heater and danger of burning it out be obviated.

The method of feeding is as follows: The feed enters the lower front manifold of the heater, passes through a series of tubes to the lower manifold at the back and back again to the next higher front manifold; and so on back and forth until it enters the heater drum outside of the boiler casing, from which it passes to the main steam and water drum of the boiler. The top heater manifold at the back is also connected with the first front manifold by two return pipes, one on each side of the heater, each connection containing a check valve opening towards the front. The former manifold is also connected with the heater drum, into which is inserted a small relief valve insuring the heater against the closing of all valves between it and the main steam drum. When the feed is constant, all the aforementioned tubes and manifolds are completely filled with water; but should the feed be stopped at a

time when the boiler is steaming rapidly, steam would be generated in the heater tubes and blow the water before it into the main drum leaving the heater tubes dry, were it not for the return connection from the top to the bottom manifold, which establishes a circulation within the heater. By this arrangement, a large body of water is not forced into the main steam and water drum, but only steam due to water that is actually evaporated in the heater. The makers state that in a test made by them, a glass water gauge was placed on the heater and one on the main water drum, the water being allowed to evaporate in the heater until its height could be seen in the glass; the height of water in both glasses was then noted, the feed pump being stopped. The boiler was steaming rapidly, and 9 inches of water was evaporated from the main water drum while only $1\frac{1}{2}$ inches was evaporated in the heater. At this rate of evaporation, the heater would never burn out, as a supply of water would be needed for the boiler before that within the heater could be evaporated. During the time that the feed pump was stopped, the rush of water could be heard passing the check valve in the return connection between the manifolds.

The glass water gauge was at the front of the boiler, on one side, and was connected to the steam space of the drum at the top by a $\frac{3}{4}$-inch pipe, and to the water space at the bottom, by a $1\frac{1}{4}$-inch pipe in the head of the drum and 6 inches from the bottom thereof. Another glass gauge was on the heater to indicate the water line when the feed is shut off.

The feed water was supplied through a $1\frac{1}{2}$-inch pipe by a Blake duplex pump with cylinders $6 \times 3 \times 7$ inches stroke. A thermometer in an oil cup was placed in the pipe just before its connection with the heater, and a second one in the pipe after leaving the heater. Another thermometer was placed in the feed tank.

The feed water measuring tank, which was of iron, was located immediately above the feed tank and on accurate platform scales.

The draft was forced by a steam jet at the base of the smoke pipe and by a Sturtevant fan. The following are the particulars of the fan and engine:

Diameter of cylinders (2), inches	3
Stroke, inches	4½
Diameter of fan, inches	36
Width of blades, inches	16
Diameter of fan inlet, inches	27
outlet, inches	22

The following are the particulars of the boilers :

Width of opening to ash pit, inches	8
Length of opening to ash pit, feet	4
Length on floor, feet and inches	10–6
Width on floor, feet and inches	8–½
Height of boiler proper, feet and inches	12–10⅝
Height of boiler and heater, feet and inches	15–7
Tubes, lower nest, diameter, inches	4
length, feet	7
number	66
upper nest, diameter, inches	2
length, feet	7
number	165
side, diameter, inches	4
length, feet	7
number on each side	12
Water boxes, square, inches	6
number on each side of furnace	4
Steam drum, diameter, inches	48
length, feet and inches	9–9
steam pipe, diameter, inches	3
Feed water heater:	
tubes, number	125
diameter, inches	2
length, feet	3
length, feet and inches	5–7
width, feet and inches	3–8
Smoke pipe, diameter, inches	38
top above grate, feet	55
Safety valves, number	2
diameter, inches	2½ and 4
Length of grate, feet and inches	5–6
Grate surface, square feet	38.5
Heating surface, lower nest of tubes, square feet	462
upper nest of tubes, square feet	604.6
header (tube) surface, upper, square feet	36.66
lower, square feet	37.40
side tubes and boxes (½), square feet	115

Heating surface, tubes from headers to drum, square feet	52
drum, square feet	24
front cross-box and tubes, square feet	5 58
total in boilers, square feet	1,337.24
feed water heater, square feet	215
total boiler and heater, square feet	1,552.24
Weight of boiler, feed water heater, casing, grate bars, foundation, etc., pounds	39,818
water at 60° Fahr. in heater and in boiler at steaming level, 5 inches in glass, pounds	9,439
boiler complete with water, pounds	49.257
total, per square foot of heating surface, pounds	31.7
Same per square foot of grate surface, pounds	1,279.4

Steam having been raised to a pressure of 160 pounds, with water at a height of 5 inches in the gauge glass, the fires were hauled and lighted with wood at 12·06 P. M., at which time the test was held to commence, the water level having been noted and the first set of observations made. The blower was started at 12·11, and the steam jet at 1·30.

The coal burned was a fair quality of Pocahontas semi-bituminous, and contained about 73 per cent. of fine coal; it was rather damp. Samples from each barrow were thrown into two iron boxes and placed near the steam drum of the boiler to dry; after drying for twelve hours, the weight in each case was found to have fallen from 25 to 22 pounds, or 12 per cent. The coal burned with a white flame, and smoke showed at the top of the smoke pipe during the charging of the furnace; this soon afterwards lessened to a light thin smoke.

The method of firing was to charge the furnace heavily at the doors, and to push and spread the coal back as soon as it was moderately caked.

The following is an analysis of the coal as made by Professor Stillman, of the Stevens Institute of Technology, Hoboken, N. J.:

Volatile and combustible matter, per cent	18.14
Fixed carbon, per cent	75.92
Sulphur, per cent	·75
Ash, per cent	5.19
	100.00

The pyrometer showed rapid fluctuations during firing which were probably greater than the actual changes in temperature, and possibly due to the sudden change affecting the outer casing of the pyrometer before reaching the inner expanding metal. The lead and zinc suspended in the base of the pipe were entirely melted, and the antimony melted off at the corners, the body remaining intact, indicating a temperature at times above the melting point of antimony (806° Fahr.), but not lasting long enough to effect fusion. At night, some red flame showed at the top of the smoke pipe at intervals, but none was visible during daylight.

It was found from the half-hourly observations of the thermometers in the feed pipes, before and after leaving the heater, that the feed water was raised in temperature 98.85 degrees, going into the drum at an average temperature of 157.42 degrees.

Tables I and II give the log of the barrel calorimeter tests, and the average quality of the steam calculated therefrom is $Q = .94308$.

Tables III and IV give the corresponding evaporative results.

Tables V and VI give the evaporative results corresponding to the dryness of steam as determined from the Carpenter formula.

Tables VII and VIII give the complete log of the test. The temperature of the steam at boiler (in main steam pipe) was taken from the upper thermometer of the throttling calorimeter, and that "at calorimeter," after passing through the $\frac{1}{16}$-inch orifice of the calorimeter to atmospheric pressure. The average of the latter temperatures is 277.4 degrees, and by Carpenter's formula,

$$Q = \frac{y - q + 0.48\,(t' - t)}{v},$$

in which

y = total heat of steam at atmospheric pressure,
q = heat of water at boiler pressure,
t' = calorimeter temperature,
$t = 212$,
v = latent heat at boiler pressure,

the value of Q is .980781, or the moisture is 1.9219 per cent., and the results in Tables V and VI have been calculated for this value of Q.

A calibration of the Barrus calorimeter was made on the day following the test with the fires in the boiler nearly dead and the furnace doors open, no steam leaving the boiler except through the calorimeter. The steam pressure was 175.2 pounds absolute, its temperature 366 degrees, and the temperature by the calorimeter thermometer, 284.5 degrees. As the steam flowing through must have been dry saturated, a temperature of say 285 degrees must be a standard for dry saturated steam under the above pressure; and as the lowest recorded temperature of this calorimeter during the test was 268 degrees, the greatest fall in temperature was 17 degrees. As the latent heat of steam at 366 degrees is 855.5, and the specific heat of superheated steam is 0.48, there would be required for 1 per cent. of moisture a fall of $\frac{8.555}{0.48} = 17.8$ degrees. As the fall was 17 degrees, the percentage of moisture is $\frac{17}{17.8} = 0.9555$, which would give $Q = .990445$.

But as the average difference of temperature for the whole test was only $285 - 277.4 = 7.6$ degrees, the average moisture in the steam was only 0.427 per cent. In other words, it was less than one-half of one per cent., and the quality of the steam was $Q = .99573$.

As the Carpenter and Barrus formulæ agree very closely, it seems quite certain that the steam delivered by the boiler during the test contained an average of less than one per cent. of moisture. During the whole test the water level was very steady, and when the safety valve opened suddenly, the water rose slowly an inch or two, and when it closed, which it did suddenly, the level dropped from two to three inches. The stop valve was opened and shut during eight to ten minutes, and the water rose and fell about the same as when the safety valve opened and shut. No serious disturbance was shown in the glass and no difficulty was experienced in manipulating the boiler at any time during the test; the feed gave no trouble, the water level remaining steady and easily regulated.

The force of the steam jet, blower and feed pump was varied from time to time as was deemed necessary by the attendants,

but everything ran evenly except at the time of charging the furnace, and then very little change was necessary.

The sides of the boiler as high as the furnace water boxes were cool, about 100 degrees, while above that, the temperature was much higher, about 150 degrees; and the spaces about the boiler, except in front, were about 90 degrees. The fire room thermometer was hung about 4 feet from the inner front corner of the boiler, out of drafts, but was at once affected when the furnace doors were opened.

After the test was completed the fires were hauled and the water blown out. Two workmen with two helpers then split both ends of a lower tube, drew it out, put in a new one, expanded it, and replaced the caps ready for water in 22½ minutes. The internal surface of the tube was quite clean, but there was considerable soot baked on the outside, more of it near the ends than the center.

There was considerable soot on the tubes, as no cleaning or sweeping had been done during the test, and the fire was cleaned only once during the 24 hours. After the test, 236 pounds of soot were removed by a steam jet.

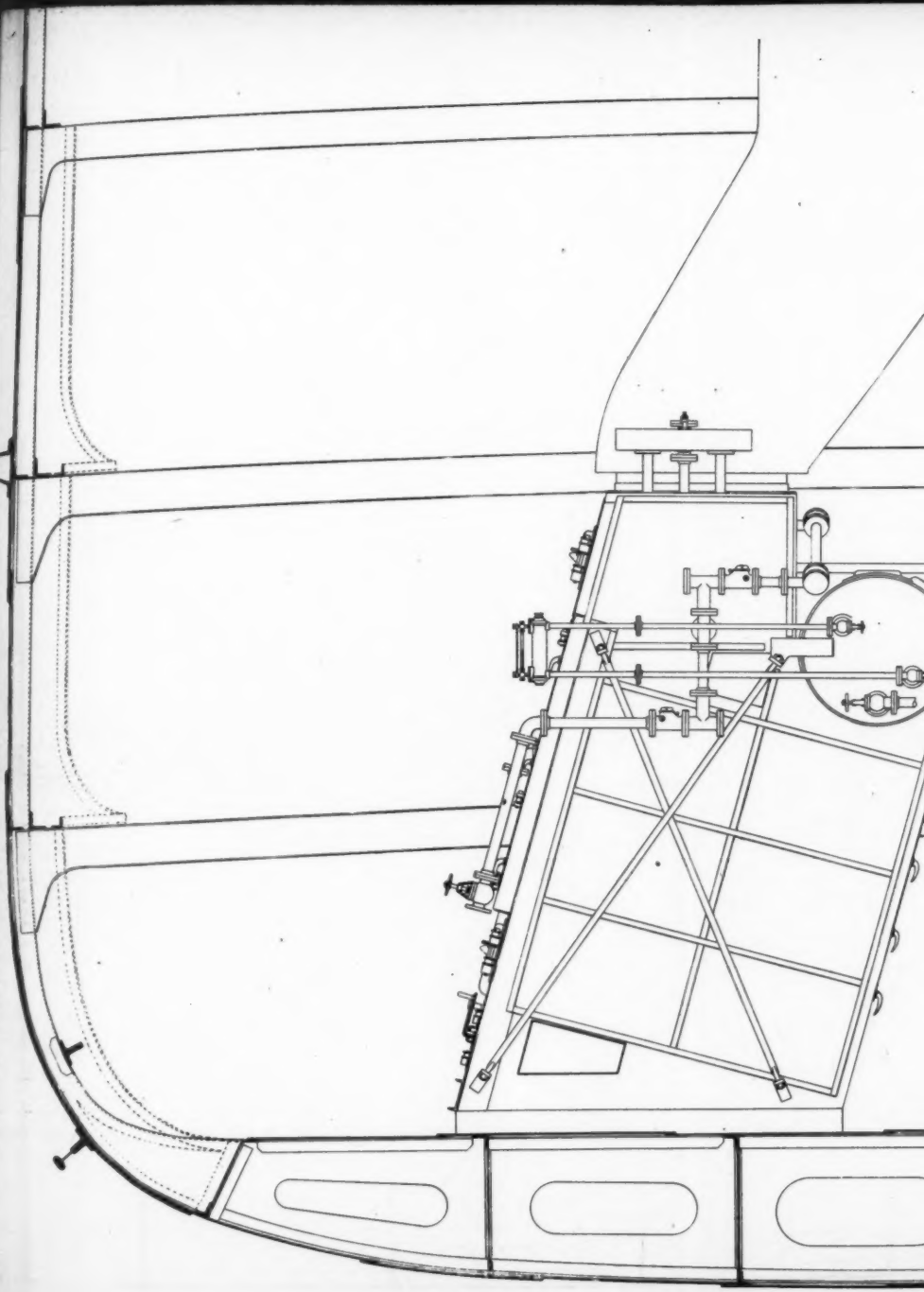
No leaks were discovered in the tubes or other parts of the boiler, nor any signs of wear except the furnace door linings, which were considerably warped from the intense heat, some flame at times escaping around the edges of the door.

The feed heater gave no trouble and operated very satisfactorily.

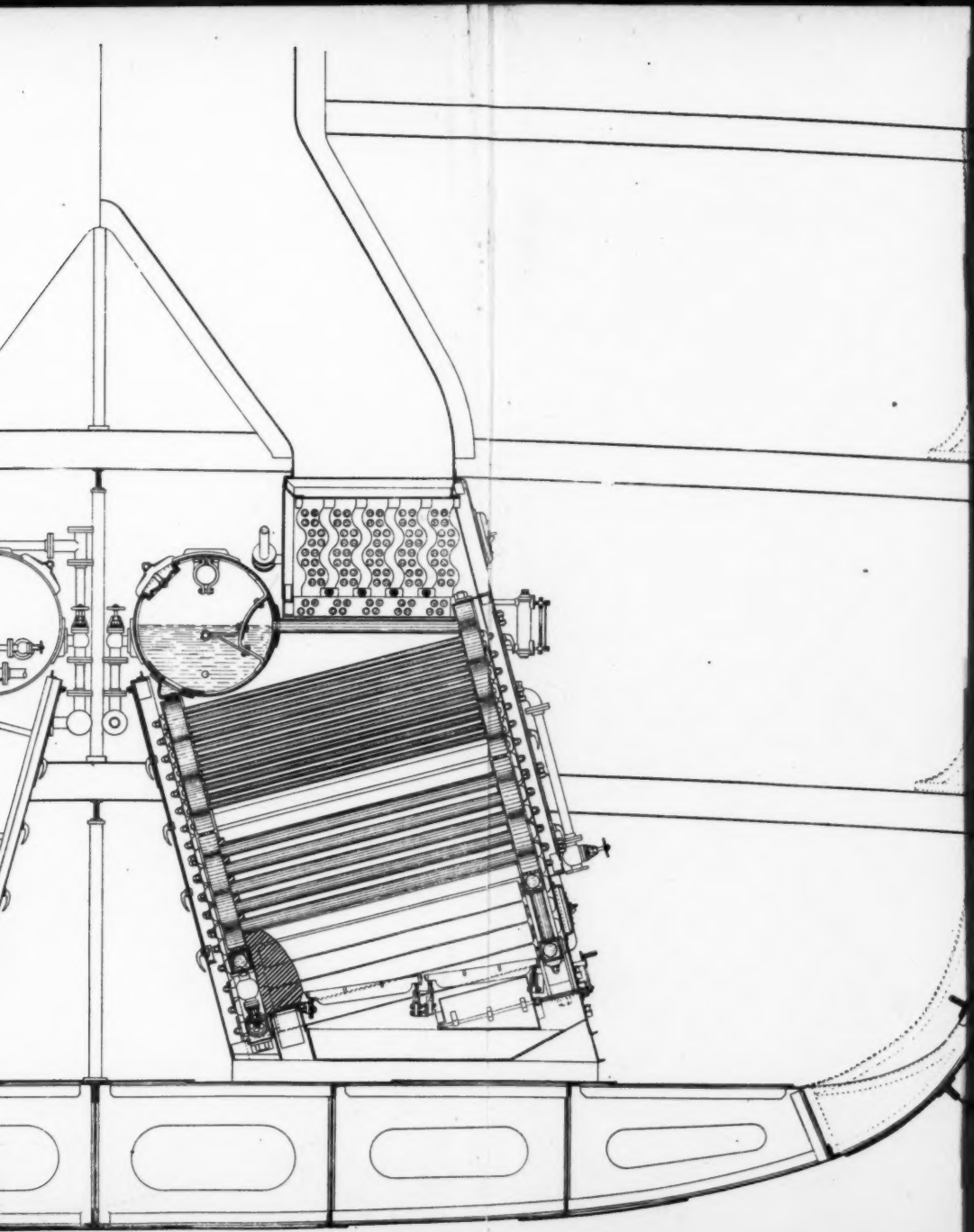
An examination of the air pressure columns in the tables shows that, at times, the pipe connected with the furnace gauge must have been choked, so that the reading of the gauge is not to be relied upon.

The boiler which has been described is one of the first of the marine type designed by the Babcock and Wilcox Company, and since it was built, important modifications have been made in the general type, which modifications will be apparent from an examination of Fig. 2, which shows the boiler which has been constructed for the Plant steamer, building by the Newport News Shipbuilding and Dry Dock Company.

A marked reduction in the height of the boiler has been

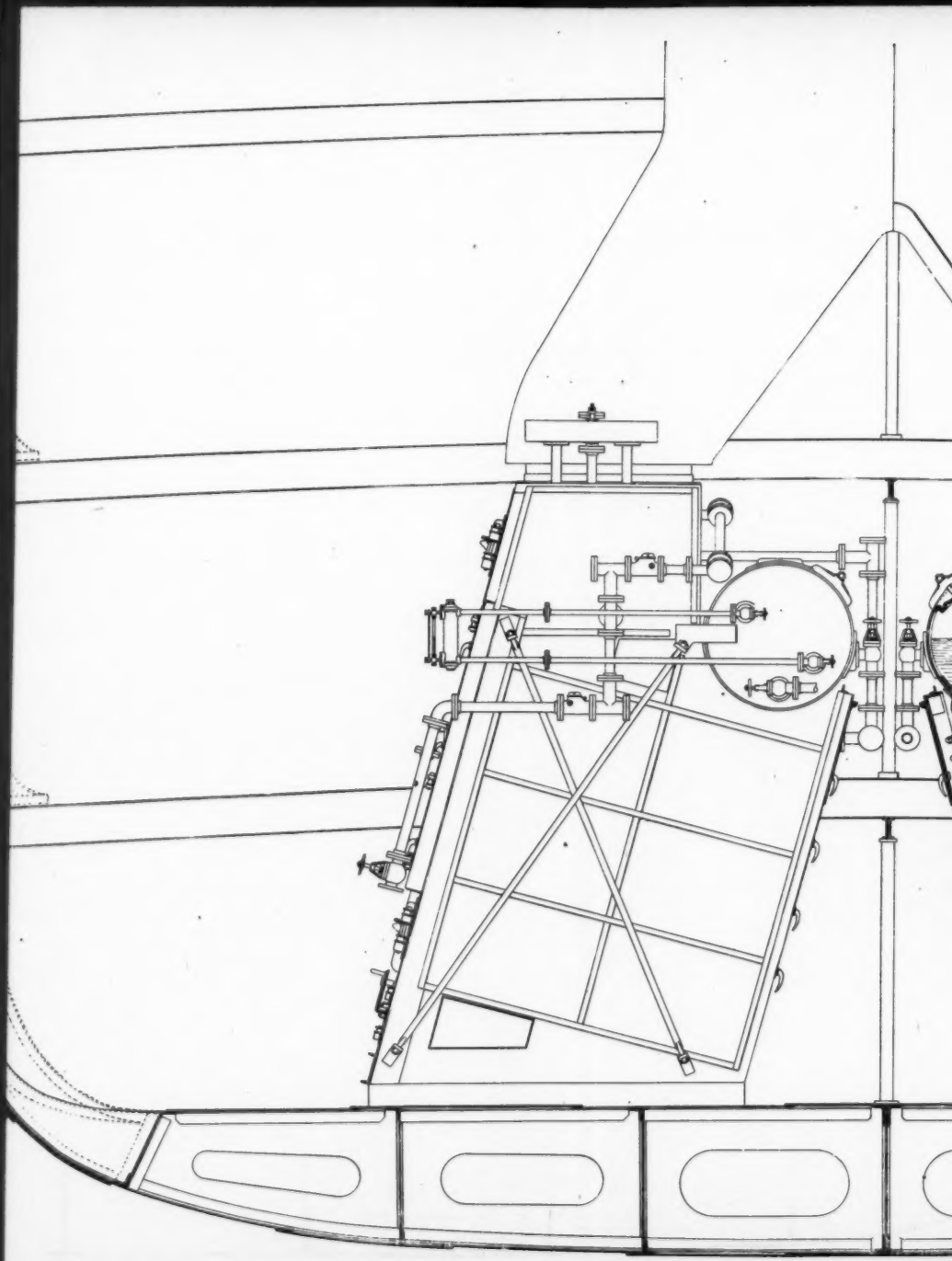


BABCOCK & WILCOX E



X BOILERS FOR THE PLANT STEAMER.

FIG. 2.



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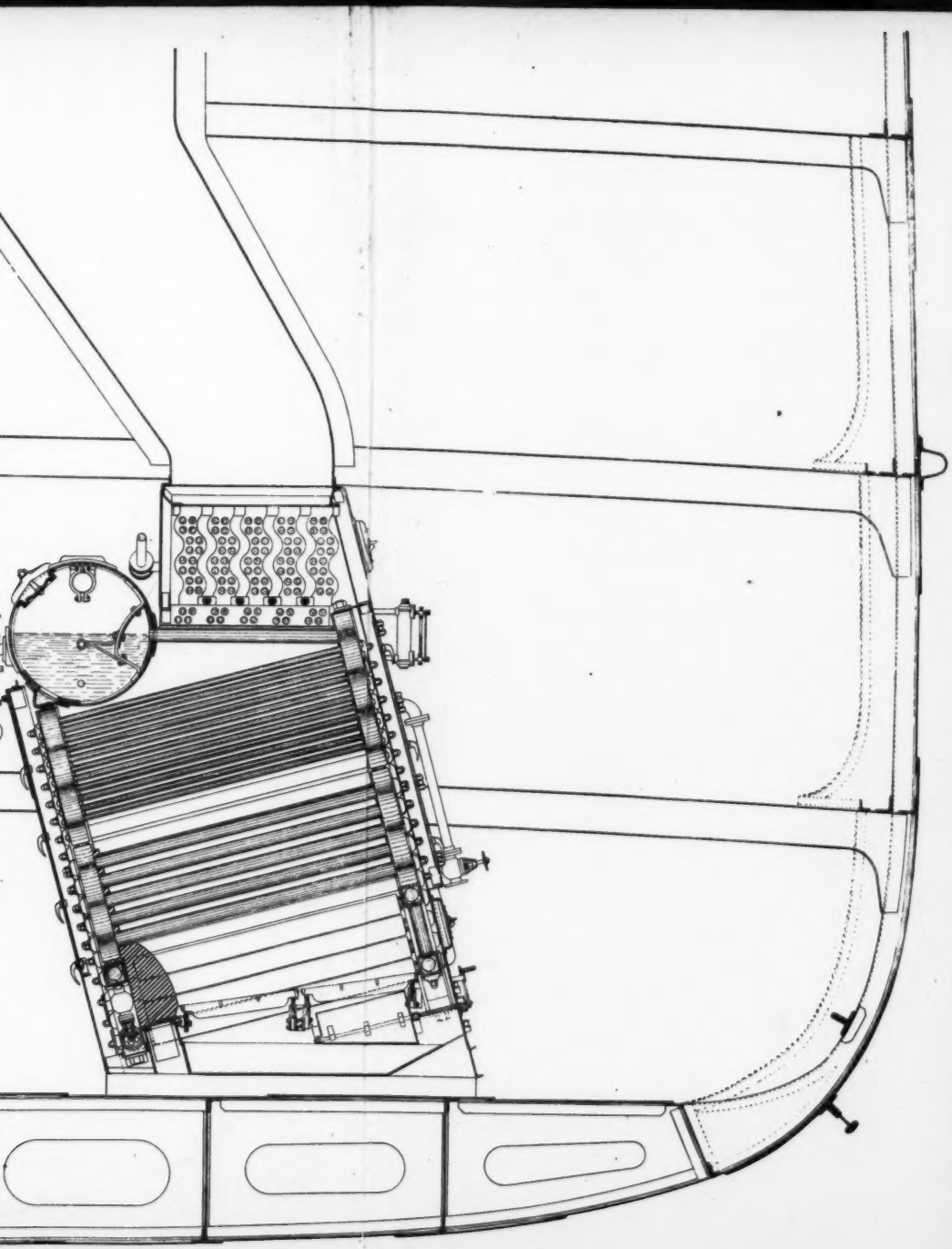
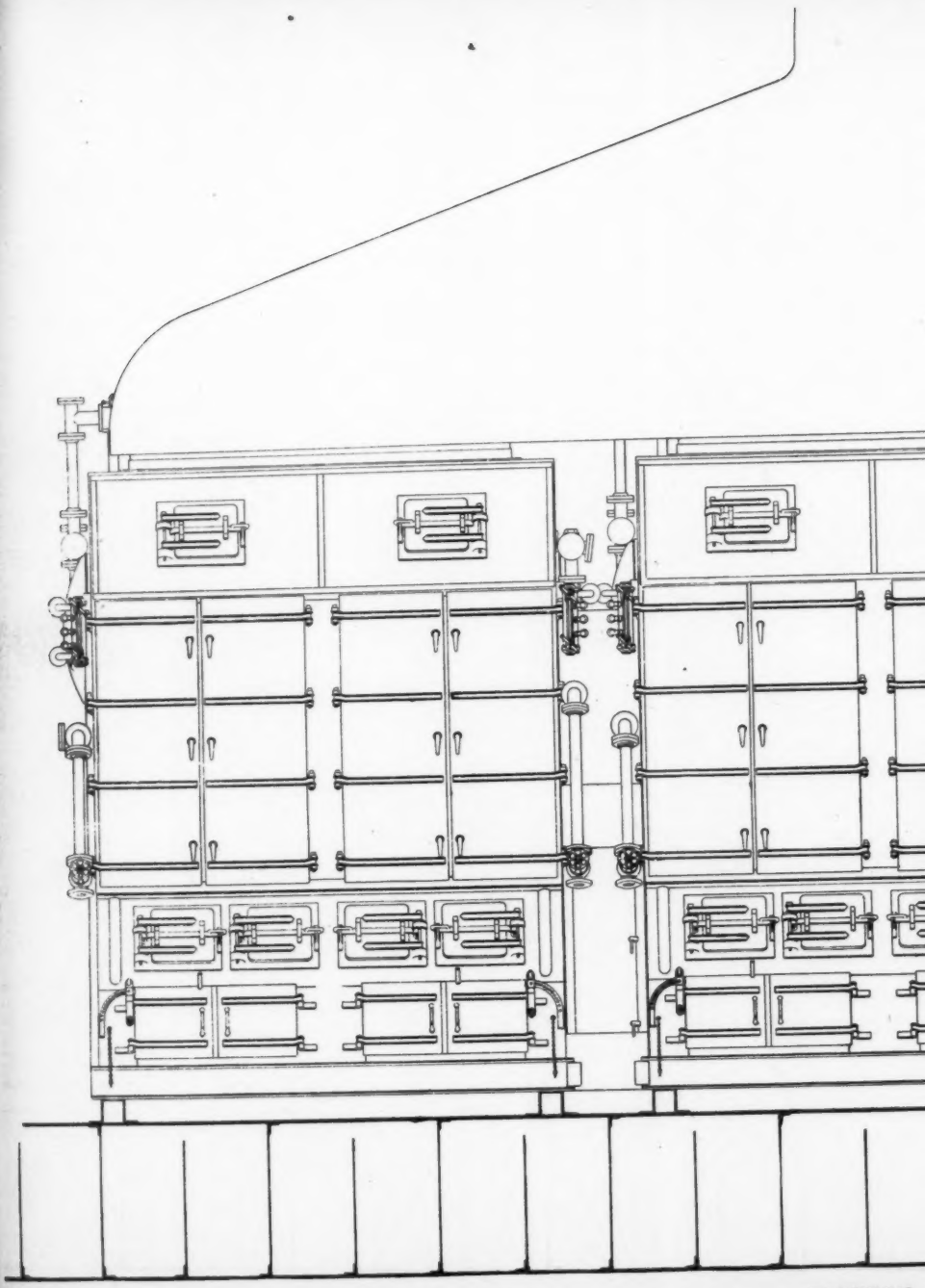


FOR THE PLANT STEAMER.

FIG. 2.



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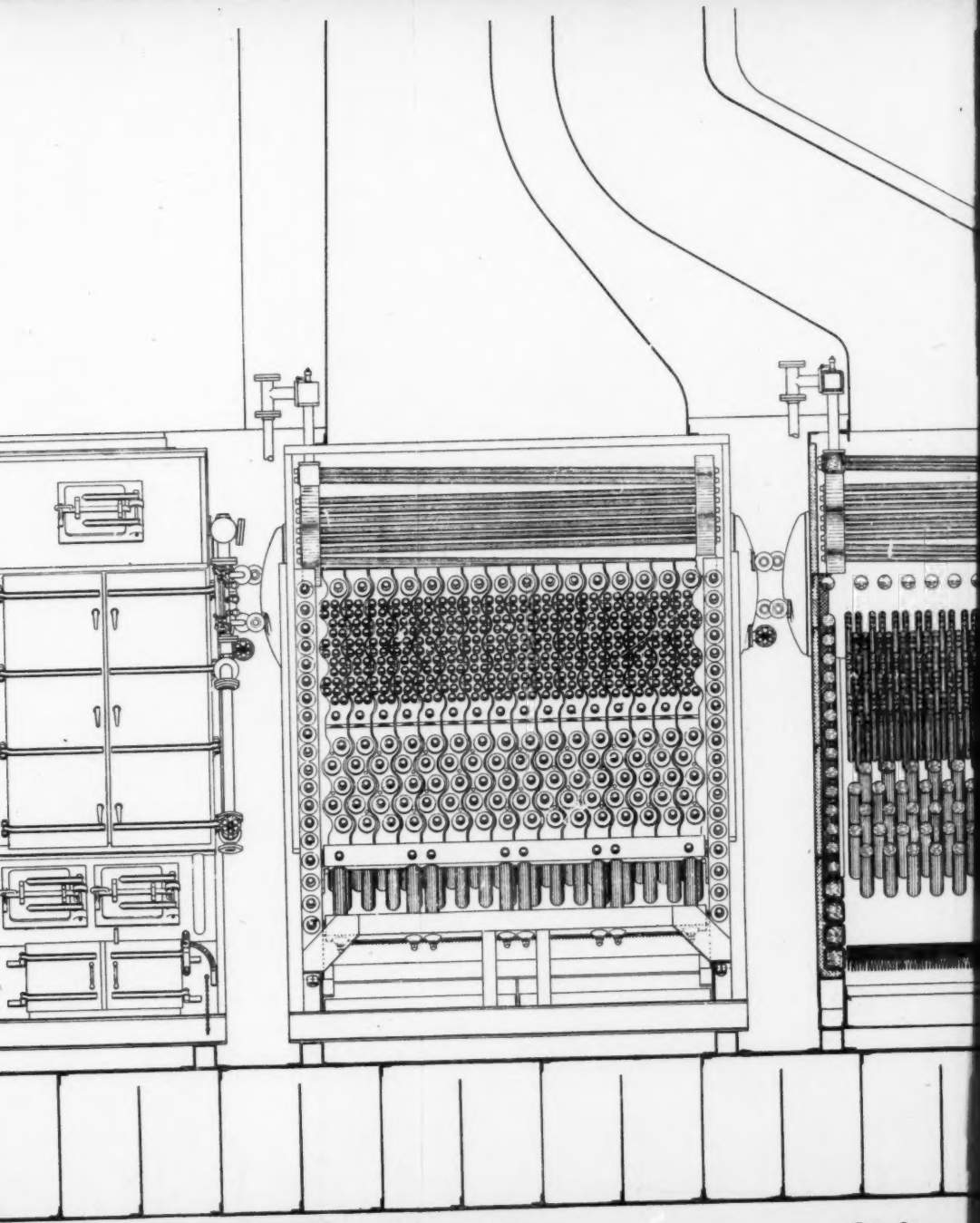
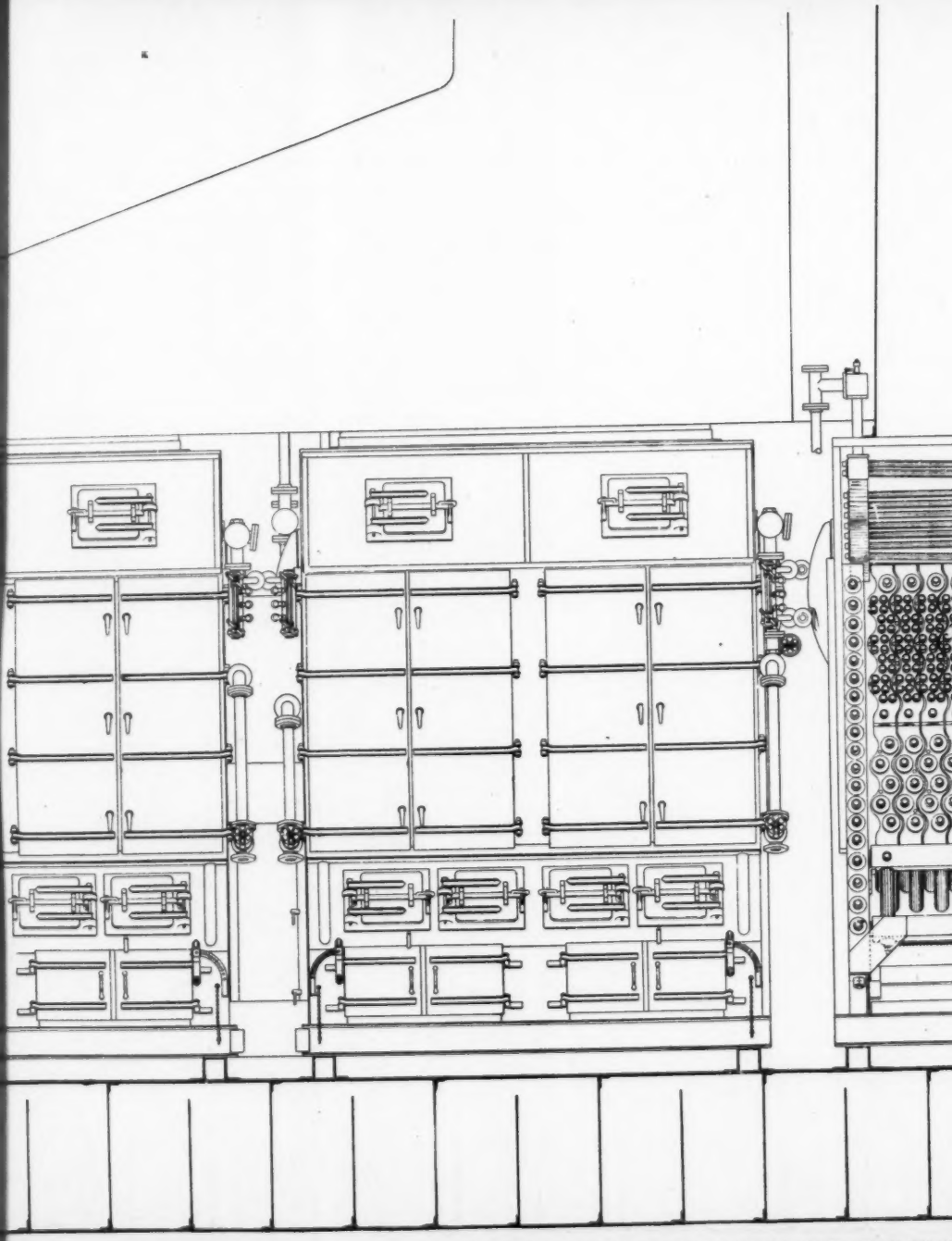


CK & WILCOX BOILERS FOR THE PLANT STEAMER.

FIG. 2.



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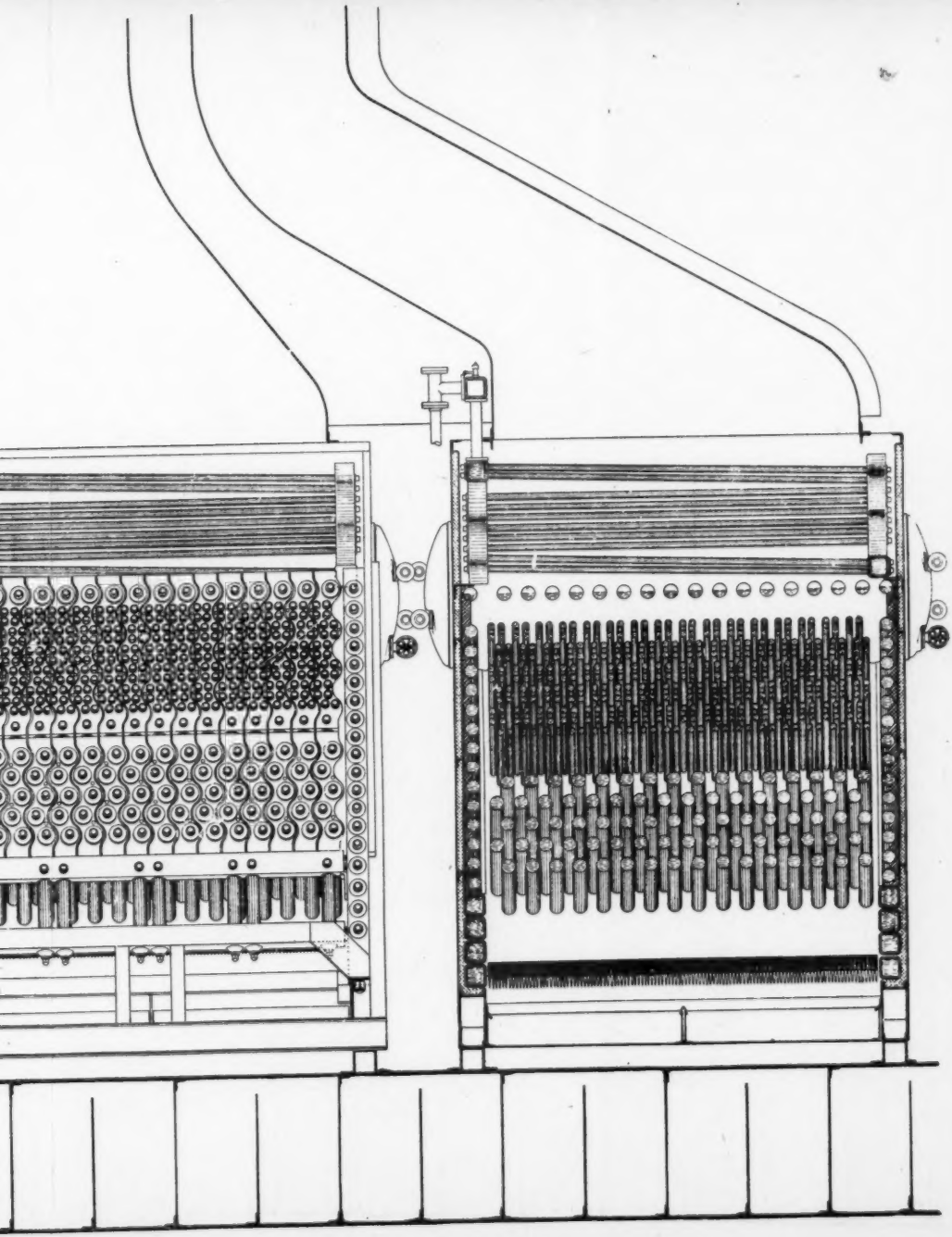

PLANT STEAMER.

FIG. 2.

affected by arranging the tubes in clusters of four instead of three in the upper headers. A change in the method of supporting the front sections has also been made. In the boiler tested, the weight was taken by an I-beam just over the furnace door, which not only required protection from the fire, but tended to make the boiler too rigid; this has been changed in the new design, where the sections are supported by nipples expanded into the cross box, as shown, which gives greater flexibility.

The tubes forming the water sides of the boiler and the headers at each end of these tubes are extended clear down to the bottom and fastened to the keelson, making four corner columns as a solid support. On the top of the two front columns is placed a forged steel cross box connected with all the headers, this cross box being in turn connected to the drum by circulating tubes at the top. From the cross box forming the beam, thus supported on its ends, are suspended all the sections by means of expanded nipples, one end being expanded into the cross box and the other into the top of the header.

In the boiler tested, there was no provision for cleaning off the outside surface of the tubes while running. In the new boiler, however, thimbles are screwed into the headers so that a steam jet may be used.

The hand hole bolts have a ball head, so that undue strain may not be brought on one corner of the plate, as is sometimes the case with square headed bolts. The body of each bolt is necked down below the diameter of the thread to insure that the strain put upon the bolt is distributed over a greater length of metal than in the ordinary bolt, where the thread is simply cut down into the metal.

One of the most important modifications is the forged butt strap, into which the connecting nipples between the back headers and the drum are secured. By the use of this form of strap, the bent nipples of the former design are avoided. The straps are forged with a series of pockets, each of sufficient area to take the seating of a single tube connected to a single section. The metal between the pockets is depressed in such shape as to take the bursting strain of the shell on the metal, making a very stiff joint.

TABLE I.

LOG OF CALORIMETRIC TESTS, APRIL 22, 1895.

No. of test.	Time. At beginning.	Time. At end.	Average pressure of steam in lbs. absol. P.	Weights. Calorimeter. b.	Weights. W + b.	Weights. W.	Weights. W + b + w.	Weights. w.	Temperatures. t'.	Temperatures. t.	Q.	Temp. of steam by thermometer.
1	12'45	12'50	149.6	87	398	311	409	11	100.2	59.1	1.04975	353.
2	1'10	1'18	162.6	87	451	364	468.375	17.75	111.5	59	.96225	363.
3	1'25	1'29	175.6	87	450.5	363.5	468	18.5	111	59	.86733	355.
4	2'30	2'35	178.6	87	456.75	369.75	473	17.25	108	59.5	.91203	360.
5	3'15	3'19	178.6	87	450.5	363.5	467.5	17	111	59	.97072	362.
6	4'10	4'13	176.6	87	455	368	473	18	109.5	58.3	.89431	361.
7	5'08	5'11	176.6	87	450	363	467.5	17.5	109.5	57.6	.93690	357.
8	6'12	6'14	176.6	87	450.5	363.5	469.5	19	113.7	57.8	.92557	347.
9	7'50	7'54	167.6	87	452	365	470	18	110.3	58	.94069	358.
10	9'59	10'03	173.6	87	452.5	365.5	471.25	18.75	112.1	56.7	.96472	364.
11	10'43	10'47	172.6	87	454.5	367.5	474	19.5	111.5	57.2	.89790	355.
12	11'04	11'09	172.6	87	452	365	470.5	18.5	110.9	56.6	.95349	357.
	Mean values of Q and temperature										.93963	357.7

Percentage of moisture in the steam, 100 (1—Q), 6.037.

Fires were started with wood (388 pounds = 155 pounds of coal) and coal at 12'06, and the blower engine started at 12'11, the water in the glass gauge standing at a height of 5 inches. At 1'30 the steam jet was started in smoke pipe, and at 4'53 the force of the jet and fan blast were increased.

At commencement of the test the sky was overcast, with wind from the southeast. Rain fell at 1'30 and continued until 8'30, when it cleared with wind from the west.

Coal.—Pocahontas, damp and containing a large percentage of fine coal. Smoke showed from smoke pipe on firing.

TABLE II.

LOG OF CALORIMETRIC TESTS, APRIL 23, 1895.

No. of test.	Time. At beginning.	Time. At end.	Average pressure of steam in lbs. absol. P.	Weights. Calorimeter. b.	Weights. W + b.	Weights. W.	Weights. W + b + w.	Weights. w.	Temperatures. t'.	Temperatures. t.	Q.	Temp. of steam by thermometer.
1	12'46	12'51	175.6	87	450.5	363.5	469	18.5	112.2	56.8	.94570	364
2	2'22	2'25	171.6	87	457	370	475.25	18.25	111.9	56.3	1.01997	362
3	3'23	3'27	172.6	87	452.5	365.5	471.5	19	110.5	56.7	.90838	363
4	4'20	4'24	171.6	87	453	366	471.25	18.25	111.6	57	.98186	363
5	5'22	5'25	172.6	87	455	368	474	19	110.3	56.9	.90927	348
6	6'05	6'08	164.6	87	450	363	468.75	18.75	110.9	56.6	.93787	363
7	7'05	7'08	169.6	87	451.5	364.5	469.75	18.25	110.3	56.6	.91856	361
8	8'09	8'12	171.6	87	457	370	476	19	111.4	56.4	.95353	356
9	10'04	10'07	173.6	87	452.75	365.75	471.25	18.5	110.3	55.7	.95732	364
10	11'35	11'38	172.6	87	452.75	365.75	472.25	19.5	111.2	55.5	.92221	363
11	11'44	11'48	175.6	87	457	370	475	18.25	111.1	57	.97128	363
12	12'02	12'05	168.6	87	450.25	363.25	470	19.75	112	54.8	.93255	363
	Mean values of Q and temperature										.94654	361

Percentage of moisture in the steam, 100 (1—Q), 5.346.

Mean of 24 tests: Q ..... .94308
Percentage of moisture..... 5.692
Observed temperatures of steam.... 359.4

The total refuse from the fuel consisted of 236 pounds of soot, 457 of clinker and 2,163 of ashes, making a total of 2,856 pounds.

Fires were cleaned at 5'10 A. M.

At 10'06, the stop valves were opened wide to observe the effect on the water level.

TABLE III.

RECAPITULATION OF THE RESULTS OF THE EVAPORATIVE AND CALORIMETRIC TESTS, APRIL 22 AND 23, 1895.

NOTE.—All weights are given in pounds and all temperatures in degrees Fahrenheit.

TOTAL QUANTITIES.

$Q = .94308$.

Duration of test, in hours	24
Fuel consumed, Pocahontas, dry, (moisture 12 per cent)	40,811
Refuse from fuel, in dry ashes, dust and clinkers	2,856
Combustible consumed	37,955
Water fed to boiler, by tank measurement, W_1	285,936
Per cent. of the fuel in dry refuse, etc	6.998

AVERAGE QUANTITIES.

Temperature of feed water, t_1	58.5
Temperature of steam, by thermometer	362.04
Temperature of uptake	833.33
Temperature of atmosphere	58.08
Temperature of fire room	99.23
Barometer, in inches of mercury	29.939
Pressure of steam at boiler, in pounds per square inch above a perfect vacuum, 14.7 + pressure by gauge in pounds, p	171.01
Air pressure, in inches of water, at ash pit	.8893
Air pressure, in inches of water, at base of smoke pipe	.5410
Air pressure, in inches of water, in furnace	.1688
Revolutions of blowing engines, per minute	452.93

RATES OF COMBUSTION.

	Pounds of fuel.	*Pounds of combustible.*
Amount consumed per hour	1,700 4	1,581.45
Amount consumed per hour per square foot of grate surface	44.166	41.077
Amount consumed per hour per square foot of heating surface (exterior)	1.096	1.019

VAPORIZATION IN POUNDS OF WATER.

	Per pound of fuel.	*Per pound of combustible.*
Apparent evaporation, by tank measurement, from a temperature t_1 and under a pressure p	7.006	7.533
Equivalent apparent evaporation from and at 212 degrees and under atmospheric pressure	8.472	9.109
Actual evaporation, into steam of quality Q, from a temperature t_1 and under a pressure p	6.607	7.105
Equivalent actual evaporation from and at 212 degrees and under atmospheric pressure	7 985	8.590

	Per pound of fuel.	*Per pound of combustible.*
Potential evaporation, or evaporation had all the heat obtained from fuel been utilized in converting the water in boiler into dry saturated steam from a temperature t_1 and under a pressure p	6.716	7.121
Equivalent potential evaporation from and at 212 degrees and under atmospheric pressure	8.120	8.731

TABLE IV.

From the foregoing tables the following data are obtained, from which the computations for the potential evaporation are made:

Q	.94308
Average steam pressure, absolute, p	171.01
Average temperature of the feed water, t_1	58.5
(a) Number of pounds of water vaporized, $W_1 \times Q$	269,661.11
(b) Number of pounds of water carried over with the steam, $W_1 (1-Q)$	16,274.89
Total heat of steam at pressure p	1,194.4
Total heat of water at temperature t_1	26 62
(c) Units of heat required to vaporize one pound of water from a temperature t_1 and under a pressure p	1,167.78
(c^1) Units of heat required to raise the temperature of one pound of water from t_1 to the temperature due to the pressure p	314.38
(d) Units of heat required to vaporize one pound of water from and at a temperature of 212° and under atmospheric pressure.	965.8
Total heat required to vaporize the water, $a \times c$	314,904,726
Total heat required to raise the temperature of the water, $b \times c^1$	5,164,995
(e) Total heat obtained from the fuel, as measured by the steam discharged	320,069,721
(f) Units of heat obtained per pound of fuel	7,842.72
(g) Units of heat obtained per pound of combustible	8.432.87
$\frac{f}{c}$ Potential evaporation per pound of fuel, from a temperature t_1 and under a pressure p	6.716
$\frac{g}{c}$ Potential evaporation per pound of combustible, from a temperature t_1 and under a pressure p	7.221
$\frac{f}{d}$ Equivalent potential evaporation per pound of fuel from and at a temperature of 212° and under atmospheric pressure	8.120
$\frac{g}{d}$ Equivalent potential evaporation per pound of combustible from and at a temperature of 212° and under atmospheric pressure	8.731

TABLE V.

RECAPITULATION OF THE RESULTS OF THE EVAPORATIVE AND CALORIMETRIC TESTS APRIL 22 AND 23, 1895.

NOTE.—All weights are given in pounds and all temperatures in degrees Fahrenheit.

TOTAL QUANTITIES.

$Q = .980781$.

Duration of test, in hours	24
Fuel consumed, Pocahontas, dry, (moisture 12 per cent)	40,811
Refuse from fuel, in dry ashes, dust and clinkers	2,856
Combustible consumed	37,955
Water fed to boiler, by tank measurement, W_1	285,936
Per cent. of the fuel in dry refuse, etc	6.998

AVERAGE QUANTITIES.

Temperature of feed water, t_1	58.5
Temperature of steam, by thermometer	362.04
Temperature of uptake	833.33
Temperature of atmosphere	58.08
Temperature of fire-room	99.23
Barometer, in inches of mercury	29.939
Pressure of steam at boiler, in pounds, per square inch above a perfect vacuum, 14.7 + pressure by gauge in pounds, p	171.01
Air pressure, in inches of water, at ash pit	.8893
Air pressure, in inches of water, at base of smoke pipe	.5410
Air pressure, in inches of water, in furnace	.1688
Revolutions of blowing engines, per minute	452.93

RATES OF COMBUSTION.

	Pounds of fuel.	*Pounds of combustible.*
Amount consumed per hour	1,700.4	1,581.45
Amount consumed per hour per square foot of grate surface	44.166	41.077
Amount consumed per hour per square foot of heating surface (exterior)	1.096	1.019

VAPORIZATION IN POUNDS OF WATER.

	Per pound of fuel.	*Per pound of combustible.*
Apparent evaporation, by tank measurement, from a temperature t_1 and under a pressure p	7.006	7.533
Equivalent apparent evaporation from and at 212 degrees and under atmospheric pressure	8.472	9.109
Actual evaporation, into steam of quality Q, from a temperature t_1 and under a pressure p	6.872	7.389
Equivalent actual evaporation from and at 212 degrees and under atmospheric pressure	8.309	8.934

	Per pound of fuel.	*Per pound of combustible.*
Potential evaporation, or evaporation had all the heat obtained from fuel been utilized in converting the water in boiler into dry saturated steam from a temperature t_1 and under a pressure p	6.908	7 428
Equivalent potential evaporation from and at 212 degrees and under atmospheric pressure	8.353	8.981

TABLE VI.

From the foregoing tables the following data are obtained, from which the computations for the potential evaporation are made:

$Q = .980781$.	
Average steam pressure, absolute, p	171.01
Average temperature of the feed water, t_1	58.5
(a) Number of pounds of water vaporized, $W_1 \times Q$	280,441.36
(b) Number of pounds of water carried over with the steam, $W_1 (1 - Q)$	5,494.64
Total heat of steam at pressure p	1,194.4
Total heat of water at temperature t_1	26.62
(c) Units of heat required to vaporize one pound of water from a temperature t_1 and under a pressure p	1,167.78
(c^1) Units of heat required to raise the temperature of one pound of water from t_1 to the temperature due to the pressure p	314.38
(d) Units of heat required to vaporize one pound of water from and at a temperatue of 212 degrees and under atmospheric pressure	965.8
Total heat required to vaporize the water, $a \times c$	327,493,834
Total heat required to raise the temperature of the water, $b \times c^1$	1,727,405
(e) Total heat obtained from the fuel, as measured by the steam discharged	329,221,239
(f) Units of heat obtained per pound of fuel	8,067
(g) Units of heat obtained per pound of combustible	8,674
$\frac{f}{c}$ Potential evaporation per pound of fuel, from a temperature t_1 and under a pressure p	6.908
$\frac{g}{c}$ Potential evaporation per pound of combustible, from a temperature t_1 and under a pressure p	7.428
$\frac{f}{d}$ Equivalent potential evaporation per pound of fuel, from and at a temperature of 212 degrees and under atmospheric pressure	8.353
$\frac{g}{d}$ Equivalent potential evaporation per pound of combustible from and at a temperature of 212 degrees and under atmospheric pressure	8.981

TABLE VII.

LOG OF EVAPORATIVE TEST, APRIL 22, 1895.

Reference number.	Time.	Steam pressure by gauge at boilers.	Barometer, in inches of mercury.	Pounds of fuel consumed.	Pounds of water fed to boilers.	Temperatures.						Air pressure in inches of water.			Revolutions of blowing engines.	Remarks.
						Feed water, t_1.	Steam by thermometer.		In uptake.	Atmosphere.	Fire room.	Ash-pit.	Furnace.	Base of smoke pipe.		
							At boiler.	At calorimeter.*								
1	12·36	135.4	29.97	1,400	.....	62	359	279	640	66	100	.80	.25	.34	368a.	a Started fires with wood and coal at 12·06, and blower engine at 12·11. Water level 5 inches in glass.
2	1·06	133.4	.96	1,200	9,612	62	363	281	500	67	100	.87	.05	.41	535	
3	1·36	159 4	.96	1,000	.....	63	360	284	500	68	106	.79	.10	.44	502b.	b Started steam jet in smoke pipe at 1·30.
4	2·06	160.4	.95	800	12,144	63	363	284	500	65	103	.67	.10	.50	442	
5	2 36	162.4	.95	800	.....	62	359	286	650	64	103	.72	.15	.41	424	c Increased jet and blast at 4·53.
6	3·06	162.4	.95	800	12,442	63	358	286	700	63	103	.65	.15	.52	368	
7	3·36	161.4	.95	800	.....	63	360	285	780	62	103	.83	.15	.52	397	
8	4·06	160.4	.94	800	12,786	63	363	285	650	61	98	1.05	.15	.56	512	
9	4·36	149 4	.94	800	.....	62.5	362	284	840	61	96	.78	.20	.51	490c.	
10	5·06	160.4	.94	800	12,132	62.5	363	286	1,020	59	94	.92	.15	.64	470	
11	5·36	160.4	.94	1,000	.....	61.5	362	284	800	60	97	.79	.10	.63	475	
12	6·06	160 4	.94	1,000	13,296	60.5	363	285	1,200	60	100	1.17	.10	.68	500	
13	6·36	155.4	.94	1,200	.....	61	363	283	1,100	61	103	1.20	.10	.68	510	
14	7·06	157 4	.94	1,200	13,906	60	363	285	1,020	60	101	.72	.10	.65	484	
15	7 36	142 4	.94	1,200	.....	59.5	347	284	1 200	59	100	.50	.15	.63	385	
16	8·06	161 4	.94	1,000	13,740	59	365	280	700	58	98	1.25	.15	.60	518	
17	8 36	161.4	.94	800	.....	59	381	289	960	58	95	.50	.15	.62	502	
18	9·06	155.4	.96	1,000	12,420	58	360	276	800	56	89	1.25	.15	.86	520	
19	9·36	160 4	.96	1,200	.....	57.5	361	273	760	56	95	.79	.15	.73	462	
20	10·06	155.4	.95	1,200	13.314	57	363	274	720	54	100	1.00	.15	.70	486	
21	10·36	160.4	.95	1,200	.....	57	363	274	900	54	96	1.10	.15	.70	472	
22	11·06	157.4	.95	1,000	12,572	57	362	272	800	55	93	.77	.20	.72	408	
23	11·36	153 4	.97	1,000	.....	57	359	274	1,150	53	93	.97	.20	.62	424	
24	12·06	157.4	.96	1,000	12,224	56	363	276	1,100	53	96	.83	.15	.67	380	

* Barrus' throttling.

TABLE VIII.

LOG OF EVAPORATIVE TEST, APRIL 23, 1895.

Reference number.	Time.	Steam pressure by gauge at boilers.	Barometer, in inches of mercury.	Pounds of fuel consumed.	Pounds of water fed to boilers.	Temperatures.						Air pressure in inches of water.			Revolutions of blowing engines.	Remarks.
						Feed-water, t_1.	Steam by thermometer.		In uptake.	Atmosphere.	Fire room.	Ash pit.	Furnace.	Base of smoke pipe.		
							At boilers.	At calorimeter.*								
1	12·36	161.4	29 96	1,000	.....	56	363	273	1,000	53	90	1.17	.15	.69	423	
2	1·06	158.4	.96	1,000	12,491	56	356	277	960	50	90	.63	.15	.69	432	
3	1·36	150.4	.95	1,000	.....	56	362	274	750	50	86	.78	.15	.46	372	
4	2·06	154.4	.93	1,000	11,585	56	361	276	900	51	87	.56	.15	.50	350	
5	2·36	158.4	.93	1,000	.....	56.5	365	272	1,020	50	94	1.00	.20	.50	450	
6	3 06	158.4	.93	800	11,762	56	360	277	1,000	49	101	1.11	.15	.40	405	
7	3·36	757.4	.93	1,000	.....	56.5	356	276	580	49	107	1.06	.10	.41	539	
8	4·06	159.4	.93	800	11,794	56	362	273	720	49	102	1.24	.10	.41	495	
9	4·36	153.4	.93	800	.....	55.5	363	271	800	49	95	1.25	.10	.40	545	
10	5·06	161.4	.93	800	11,930	56	363	271	700	49	90	1 04	.15	.50	512	
11	5·36	156 4	.93	800	.....	55.5	362	268	860	51	85	.49	.15	.29	385	
12	6·06	149.4	.93	800	10,085	55.5	359	272	800	49	87	.78	.10	.37	380	
13	6·36	159.4	.92	1,000	.....	55	361	272	750	50	92	.72	.10	.43	440	
14	7·06	155.4	.92	1,000	10,517	55	364	272	600	52	93	.97	.05	.43	444	
15	7 36	152.4	.92	1,000	.....	55.5	363	273	600	55	100	.91	.05	.45	453	
16	8·06	158.4	.93	1,000	11,649	56	364	275	1,000	58	105	.80	1.00	.43	475	
17	8·36	155.4	.93	1,200	.....	57	364	272	850	63	112	92	.95	.43	468	
18	9·06	160.4	.94	1,200	11,847	57	365	275	900	63	120	1.07	.10	.43	503	
19	9·36	155.4	.94	1.200	.....	58	364	274	900	64	119	.72	.15	.60	397	
20	10·06	158.4	94	1,000	10,501	59	365	274	680	68	109	.90	.15	.56	443	
21	10 36	158.4	.94	800	.....	59	363	277	840	71	107	93	.10	.56	462	
22	11·06	159.4	.94	1,000	10,579	59	363	278	900	70	107	1.02	.10	.57	455	
23	11·36	157.4	.94	800	.....	60	363	276	900	70	110	.90	.10	.56	445	
24	12·06	150.4	.93	155†	10,608	60	362	272	1,000	72	109	.80	.15	.56	434	

† Wood. * Throttling.

TORPEDO BOAT DESTROYERS.

By John Isaac Thornycroft, Esq., and Sydney Walker Barnaby, Esq.

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Until the year 1885 the British Navy possessed no vessels specially designed to destroy torpedo boats. In that year it was decided to build a number of vessels for this purpose of about the same size and speed as the torpedo boat, but having a greatly superior gun armament. Torpedo boats then carried, in addition to their torpedo tubes, one or two machine guns of the Nordenfelt or Hotchkiss pattern, firing steel shot between 1 inch and 1½ inches in diameter and between ½ pound and 1 pound in weight. The vessels which were to serve as catchers, Fig. 1, Plate 1, were to be armed with two 3-pounder quick-firing shell guns, and three two-barrelled Nordenfelt guns. They could fire thirty shots per minute ahead and 390 per minute on the broadside. The design provided for an alternative armament of torpedo tubes, and when these were carried the two 3-pounder guns would be dismounted, leaving only the three Nordenfelts. Four such boats were built at Cowes, twenty-five at Poplar, and twenty-five at Chiswick. They were 125 feet long, of about 65 tons displacement, and had a guaranteed speed of 19 knots per hour. This speed was exceeded on the trials of many of them by between 1 and 2 knots. Before their completion the original intention of using them as catchers was abandoned, and they were fitted out as torpedo boats.

In 1886 a new class of catcher, represented by the *Rattlesnake*, Fig. 3, was built. These vessels were 200 feet long, 23 feet wide, of 550 tons displacement, with engines of 2,700 I.H.P., giving a speed of 19 knots. They were armed with one 4-inch gun and

six 3-pounder quick-firing guns besides torpedo tubes. It was found necessary to increase the size of the next torpedo boat catchers, as they were then called—the name has since been changed to torpedo gun boat—and the displacement was increased to 735 tons. Between 1888 and 1890 a considerable number of these boats was built, commencing with the *Sharpshooter*. Their length is 230 feet, their beam 27 feet, and they have a draught of 8 feet 3 inches. The engines were intended to develop 4,500 I.H.P., and to give a speed of 21 knots per hour, but difficulties being experienced with the locomotive boilers, it was found impossible to obtain more than about 3,700 I.H.P. and the speed did not exceed 20 knots per hour. Even this power was not developed without difficulty, and in 1892, when eleven new vessels of the type were built, the displacement was increased to 810 tons, chiefly in order to provide more accommodation for machinery. All but one have locomotive boilers, which develop on an average 3,700 I.H.P., giving a speed of 19½ knots. The *Speedy*, Fig. 4, of the same class, but with Thornycroft water tube boilers, obtained an increase of 1,000 H.P. on trial; and the authors believe that in ordinary service, since the stokers have become accustomed to the boilers, no difficulty is found in developing 5,000 I.H.P. Her speed is 20½ knots per hour. In vessels of the *Halcyon* class, Fig. 5, now being built, the displacement is further increased to 1,070 tons, the speed being 19 knots per hour. They have no protection against shot except such as is afforded by coal bunkers surrounding and partly covering the machinery, but their steering gear is below water. Their armament consists of two 4.7 quick-firing guns and four 3-pounder guns, besides torpedo tubes.

This growth in size of the torpedo gun boat has been accompanied by greatly improved seaworthiness, and officers and men can live on board with tolerable comfort. It will be remembered that the *Gleaner* recently crossed the Bay of Biscay in a very severe gale and proved herself an excellent sea boat. But there has been no corresponding increase of speed in the torpedo gun boats, while the speed of the torpedo boat has advanced rapidly.

The first torpedo boat was built at Chiswick for the Nor-

wegian Government in 1873, and its speed was 15 knots per hour. The next advances were made by boats built at Chiswick in 1874 and 1877, when speeds of 18.2 knots and 18.5 knots per hour were successively attained, the latter by the *Lightning*, the first British torpedo boat. In 1878, Messrs. Yarrow raised the record to 21.93 knots, in 1880 to 22.16 knots, and in 1885 to 25.1 knots per hour. In 1887, the *Ariete*, which was fitted with water tube boilers, was built at Chiswick, and she attained a speed of 26 knots per hour. In 1890, a Schichau boat is said to have reached 27.4 knots per hour, but under what conditions is not known.

There is obviously a great disparity between the speed of the modern torpedo boat and that of the torpedo gun boat. It is true that the advantage possessed by the torpedo boat, although amounting to 6 or 7 knots per hour in smootn water, is considerably reduced in a rough sea, and there is no doubt that in certain conditions of weather the large gun boats of the *Speedy* type will prove formidable foes to torpedo boats. But the want has been felt of vessels having a speed equal to that of the fastest torpedo boats in all weathers, and it has been supplied by the introduction of a new type known as Torpedo Boat Destroyers.

These are virtually enlarged torpedo boats, the increase in size being determined by the conditions laid down by the Admiralty, which were that the speed was to be at least 27 knots, and that a powerful gun armament was to be carried. The result is represented by vessels of the *Daring* type, Fig. 2, Plate 1, of which forty-two are under construction. The *Daring* is 185 feet long, and has a beam of 19 feet with an extreme draught of 7 feet. The total weight of the vessel is approximately equal to the weight of the machinery of the *Halcyon* class, but her indicated horsepower is 31 per cent. geater than that of the *Halcyon*. The armament consists of one 12-pounder quick-firing gun mounted on the conning tower, and five 6-pounder quick-firing guns, four of which are on the broadside and one on the center line aft. Figs. 6, Plate 1, show a design in which five guns can fire in the line of the keel ahead. There would be two other guns on the broadside which are not shown. A 12-pounder is mounted on

the conning tower, the smaller guns being 1-pounder Maxim guns with automatic belt feed. It is possible that this may be too small a gun to stop a torpedo boat, but upon this point the authors offer no opinion, as it could only be decided by trial. It is said to be capable of penetrating 1¼ inches of iron at 600 yards, and can fire 200 rounds per minute if required. This rapidity of fire would be of great service in keeping down the fire of the enemy. It may be objected that bow guns are unfavorably placed on account of the spray which comes on board even in moderate weather when the boat is driven at high speed against a head wind. The authors believe that a horizontal canvas screen arranged as shown in Figs. 6 would protect the men at the guns from the spray, and might prevent its coming on board altogether. The screen would be rigged out on hinged stanchions at the level of the deck, and its height above the water would enable it to be retained in position in any but very rough weather, when it could be readily stowed by turning back the stanchions supporting it.

All of the Chiswick vessels have now passed their official trials with the following results in regard to speed on three hours' trial:—

	Knots per Hour.
Boxer,	29.175
Ardent,	27.973
Bruizer,	27.970
Decoy,	27.763
Daring,	27.706

Fig. 7 is a progressive speed curve of the *Daring* at about her designed displacement. Changes in the machinery after she was laid down, in order to obtain greater power and a more elaborate fitting out of the vessel required by the Admiralty than was contemplated by the authors when the design was prepared, caused her to be somewhat more deeply immersed when officially tried. Three runs were to have been made at each speed, but after the first and second of the last series had been completed, giving a speed of 28.2 knots and 28.6 knots per hour respectively, the air-pressure in the stoke holds was increased and the steam was raised to the full pressure that the safety valves would hold, so

that these were blowing off during the whole of the final run. The engines responded to the higher pressure with an increase of ten revolutions per minute, and in this run, made against the direction of the tide, but in practically slack water, a speed of 29.268 knots per hour was attained, the engines developing 4,735 I.H.P.

On the 8th January, 1895, the *Boxer* with her full load on board attained a speed of 29.314 knots as an average of six runs on the measured mile. As the authors believe this to be the highest average speed hitherto attained by any vessel, it may be of interest to give particulars of these runs.

Steam-pressure.	Vacuum.	Mean revolutions per minute.	Time.	Speed.	First mean.	Second mean.
Lbs. per sq. in.	*Inches.*		*Mins. Secs*	*Knots*	*Knots.*	*Knots.*
210	26¾	409	2 11·4	27.397	28.926	
210	26¾	414	1 58·2	30.456	29.312	29.119
210	27	418	2 7·8	28.169	29.442	29.377
210	26½	418	1 57·2	30.716	29.420	29.431
210	26½	416	2 8·0	28.125	29 239	29 329
210	26½	413	1 58.6	30 354		
						29.314

The mean air pressure in the stoke holds was 2½ inches. During the official trial on the 25th January the mean speed of a three hours' run was 29.175 knots per hour.

The propulsive coefficient is between 0.60 and 0.63, a higher value than is generally obtained in large ships. One explanation which has been given of the apparently superior performance of small vessels, is that the indicator does not give a correct measure of the power developed by very fast running engines, but underlogs it. As the size of the engines is increased and the rate of turning diminished, an allowance has to be made for reduced propulsive efficiency. If the indicator could always be depended upon, the Admiralty coefficient $\frac{V^3 D^{\frac{2}{3}}}{I.H.P.}$ should slightly

increase in value in the case of similar vessels driven at corresponding speeds as the dimensions are increased. This is because the effect of surface friction is less on the larger vessel. But the smaller propulsive efficiency due to the more accurate measurement of the power may cause the larger vessel to give an apparently inferior performance.

The curve of Admiralty coefficients $\frac{V^3 D^{\frac{2}{3}}}{I.H.P.}$ is shown in Fig. 7. It is a maximum at a speed of 12 knots, and falls to its lowest value at about 24 knots per hour, the speed at which the greatest wave making occurs. Beyond 24 knots it rises gradually, and small increments of power give a considerable increase of speed above 27 or 28 knots per hour.

The wave profile at 28 knots per hour is shown in Fig. 8, Plate 1. It will be noticed that there is very little squatting by the stern. The large area of the load water plane at the after part of the vessel prevents any great change of trim at that place, and the immersion of the stern is actually less at full speed than when at rest, because the water leaves it perfectly cleanly at the abrupt corner formed by the buttock lines.

Figs. 9 show the stability curve with all weights on board and 30 tons of coal in the bunkers. The metacentric height in this condition is 2.48 feet. The righting moment is a maximum at 46°, and vanishes at 95°. With the bunkers empty the metacentric height is 2.58 feet, and stability vanishes at 96°. With bunkers full the metacentric height is 2.21 feet, and the vanishing angle 90°. There is a noticeable change in the conditions of stability at full speed. The vessel appears to be more tender; and although this impression is perhaps chiefly due to the greater heeling effect of small movements of the helm at high speed, the stability is actually reduced as compared with the normal still water condition. The change in the water line, which falls in the wide part of the vessel amidships and rises at the finer parts of the bow and stern, lowers the metacenter. Vessels of small initial stability and of a form which, when driven at high speed, causes the water to pile up at the bow and stern and fall considerably amidships, have been known to become unstable when so

driven. The change in metacentric height due to the wave profile in Fig. 8, Plate 1, is only 2 inches, assuming that the hydrostatic pressure at each immersed section remains unchanged by the wave motion. As the effect of the wave motion must be to increase to some extent the pressure on those sections where the immersion is reduced, and to reduce the pressure on those sections where the water is raised, the fall in metacentric height cannot be greater than that stated.

In Fig. 10, Plate 1, W W is the curve of weights. Upon a base line proportional to the length of the vessel, ordinates are set up at intervals of $5\frac{1}{4}$ feet, representing the weight of a section of the vessel $5\frac{1}{4}$ feet long, with all its contents. A curve drawn through those ordinates encloses an area proportional to the total weight or displacement of the vessel. B B is the curve of buoyancy, ordinates at any point representing the immersed area of the corresponding section. The areas of the curves of buoyancy and weight are equal. When the curves cut one another the sections are said to be waterborne. It will be seen that for 20 feet from the bow the weight exceeds the buoyancy. The conning tower with the 12-pounder gun upon it, the three boilers and the engines cause the curve of weight to show above the curve of buoyancy. The pinnacle occurring in the curve at the after end of the engine room is caused by the accumulation in the same section of the weights of four cylinders, tanks and hot wells. The hump at the stern represents the combined weight of rudders, screws, shaft brackets and steering engine. From the curves W W and B B the curve of loads L L is constructed, and this curve passes below or above the line according as the weight exceeds or is in defect of the buoyancy. It, of course, crosses the line at waterborne sections. S S and M M, the curves of shearing forces and bending moments in still water, are deduced from the curve L L. The maximum shearing forces occur at waterborne sections and the maximum bending moments where the curve of shearing forces crosses the line. The maximum bending moment in still water is a hogging moment of 236 foot tons. The condition of loading is with all sea-going weights on board and 30 tons of coal in the bunkers. In Fig. 11 the

Daring is shown floating on the crest, and in Fig. 12 in the hollow, of a wave of her own length and $9\frac{3}{4}$ feet high. In the former case a hogging moment is produced equal to $\frac{1}{27.8} \times W \times L$, and in the latter a sagging moment equal to $\frac{1}{20.3} \times W \times L$, W being the weight of the vessel in tons and L its length in feet. At the section where the greatest bending moment occurs the stress upon the material amounts to 6.4 tons per square inch, so that there is an ample margin of strength even under such trying conditions as those illustrated. Figs. 13, Plate 1, show the two balanced side rudders. Their combined area is $\frac{1}{27.7}$ of the area of the immersed longitudinal vertical section of the vessel. The screws revolve within 3 inches of the inner faces of the rudders, which are curved to a radius somewhat greater than that of the propellers. The rudder heads lie in the same athwart ship plane as the screws about which the rudders swivel. When the helm is put over, the water from the screws impinges upon them both when going ahead and astern, and in the latter case the vessel is thoroughly under control. When the helm is amidships, portions only of the rudder surfaces are in the screw race, and the friction upon them is less than it would be if the same amount of total surface were disposed in the form of a single rudder at the stern. It has been found by experiment that they offer the least resistance to the progress of the vessel when they are inclined to one another at an angle of 7°, the after edges being brought together. As the water passing the inner surfaces is moving at a higher velocity than that passing the outer surfaces, the normal pressure upon the outside is greater than the pressure upon the inside. This normal pressure has a small component in a fore-and-aft direction, due to the inclination of the rudders, which assists to propel the vessel. The propelling power of the side rudders has been proved by testing the speed of the vessel with one of them removed. The speed has always proved to be unaffected, showing that the resistance of the second rudder, which is considerable, is

compensated by the forward thrust of the water upon its external surface.

The steam steering gear is shown in the plan, Figs. 13. The rudder heads pass through stuffing boxes in the bottom of the vessel, and the weight is borne upon brackets secured to the deck. Toothed quadrants, attached to the lower parts of the rudder heads, are driven by worms actuated by gear fitted to a shaft from the steering engine. By placing one worm on the after side of the port rudder and the other on the forward side of the starboard rudder, nearly all the stress is taken off the engine seating. The quadrants are either thrust asunder or drawn together according as the helm is put to starboard or port, and the thrust, instead of tending to move the shaft endwise, only puts it into compression or tension. The valves of the steering engine are worked from the wheel forward by means of a shaft supported on roller bearings, which makes four turns to one of the steering wheel. Speeded up in this way, a shaft of very small diameter will transmit the necessary power. The times of turning circles were as follows:

	Min.	Sec.
Head to port,	1	27
Stern to port,	3	30
Head to starboard,	1	29
Stern to starboard,	3	30

The diameters of the circles were not measured, but were estimated by the Admiralty officers at three and a half lengths when turning ahead and five lengths when turning astern. The authors believe that the time of turning and the diameter of the circle ahead are unusually small for a vessel of such high speed and of 185 feet in length. The power of turning rapidly must be of considerable advantage to a destroyer when chasing a torpedo boat. The extreme helm angle is 35°. The vessel heels slightly inwards when turning at full speed, showing that the pressure upon the rudder is more than sufficient to counteract the centrifugal force tending to heel the vessel outwards. That the pressures upon the rudders are enormous at full speed may be judged from the size of the rudder heads, which are of solid

steel 7 inches in diameter. The single rudders fitted to some of the destroyers have been carried away.

The shape of the stern at the water surface naturally suggests a fear that there would be slamming beneath it. Extended experience has, however, shown that there is no tendency to slam when under way. This is partly due to the action of the screws, and partly to the fact that the great width of the stern at the water surface renders its vertical movement very limited. This tendency of the stern to follow the water surface makes it possible to place the screws higher than would be prudent if the stern were of the usual form, and the draught of water is very small in the *Daring*. It is less than that of most torpedo boats, which cannot, therefore, escape pursuit by taking to shallow water.

To render torpedo boats and destroyers as nearly invisible as possible at sea, it has generally been assumed that a uniform tint is the best, and in the British Navy a dead black is preferred. If the coloring of birds which are difficult to distinguish on the sea or shore be examined, it will be found that their form is concealed by irregular patches of color. Although the background against which they show may admit of the outline of one part being visible, other parts will match with it and will not be seen. It is possible that improvements may be made in the direction of rendering these craft less visible than at present. The destroyers have been purposely made to resemble torpedo boats as closely as possible in order that their real character may not be immediately detected by their quarry. This can only be said to have been accomplished however in those which have no more than two funnels, as no disguise is possible when three or four funnels can be discerned.

The *Daring* has two sets of three-stage compound engines, each having four cylinders. The high pressure cylinder is 19 inches in diameter, and the intermediate and the two low pressure cylinders are 27 inches in diameter, with a stroke of 16 inches. At 389 revolutions, which was the mean obtained during the six runs on the official trial, the piston speed was 1,040 feet per minute. The engines are of a novel design, and each set is divided into two parts, the high and intermediate pressure

cylinders bolted together forming one part, and the two low pressure cylinders similarly connected forming the other. It will be seen, Figs. 14 and 15, Plate 2, that the cylinders forming each pair are inclined in opposite directions from the vertical and partly overlap each other. The cranks in each pair are nearly opposite and have no bearing between them. By this means two adjacent cylinders have their reciprocating parts tending to balance one another so far as vertical movements are concerned. The two low pressure cylinders being of the same size, the balance between them is almost complete. As the cranks are not quite opposite, their weight and that of the connecting rods require a small counterbalance weight. In the forward pair of cylinders the reciprocating weights of the intermediate cylinder are in excess, and a counterbalance weight is also required. The forward and the after pairs of cranks are in effect at right angles to each other. Figs. 17, Plate 2, show an inertia diagram prepared by Mr. Mallock which gives the amounts and positions of the balance weights required. In diagrams I and II the curves marked 1 and 2 indicate force at the axis of the shaft at the cranks and eccentrics, those marked 3 the resultant force at the axis of the shaft at each pair of cranks and eccentrics, and those marked 4 the resultant couple due to the distance between the cranks. Small black circles show the positions of the cranks and the direction of the resultants when the cranks are in the positions indicated. The revolving counterweight for resultant force is marked R.W.F.; that for the resultant couple, R.W.C.; the bob-weight for resultant force, B.W.F.; and that for the resultant couple, B.W.C. The balance weights A and B and the bob-weights C and D are 570 pounds, 510 pounds, 215 pounds and 216 pounds in weight respectively. With regard to vibration in a fore-and-aft direction, there is a couple tending to rotate the shaft in a vertical longitudinal plane around a center between any two adjacent crank pins, but the cranks have no bearing between them, and are therefore so close together that the effect is slight. The angle between the adjacent cranks is so arranged that the pistons reach the opposite ends of the cylinders simultaneously, and the pressure upon the bearings is relieved throughout the

stroke. The stress on the columns is in like manner reduced by this arrangement, and it will be seen that the columns are formed by simply prolonging the main bearing bolts to support the cylinder, Fig. 16. The inclination of the cylinders to each other introduces a horizontal disturbing force at right angles to the shaft. The descending piston of the high pressure cylinder, and the ascending piston of the intermediate cylinder, are moving in the same athwartship direction. Their effect is partly, but not entirely, neutralized by the movement of the slide valves, and, as the bob-weights described by Mr. Mallock are not fitted, the rotating weights are lighter than is necessary to neutralize completely the horizontal components of the inertia forces; and consequently a horizontal vibration of the vessel is observed at certain speeds. This disappears at full speed, and the vessel being stiff in this direction the effect is never more than slight. In Fig. 7 is given a curve of indicated thrust calculated from the results of the progressive trial of the *Daring*. The indicated thrust at zero speed, which is a measure of the initial friction of the engines, amounts to 1,750 pounds. The initial friction of the *Speedy's* engines deduced in the same way is about 2,800 pounds. Both engines were fitted with equal care, but those of the *Speedy* are of the usual three-crank type, and the authors believe that the friction of the engines of the *Daring* is less than the lowest that can be obtained with engines of the ordinary type. They attribute this to certain features in the design, and they believe that an examination of these features will show that there was justification for expecting an improvement in this respect. The friction of the crank pins, due to the direct pressure on the pistons, cannot be reduced to any considerable extent by any expedient that can be adopted, but a considerable portion of the total friction of the crank shaft is due to the distortion which takes place in certain portions of the shaft when twisting moment is transmitted through a crank. Two models (exhibited), Figs. 18 and 19, have been prepared to show the effect of this distortion upon the pressure on the bearings of the crank shaft. Figs. 18 represent a single-throw crank through which a twisting moment is transmitted, and it will be seen that the crank pin is twisted and the webs are bent.

The twisting of the crank pin has the effect of displacing the center line of parts of the shaft, and the bending of the two webs connecting the pin with the shaft causes a further displacement of the same part of the shaft in the same direction. If for the sake of simplicity it be first assumed that the bed plate is perfectly stiff, and that the bearings fit the shaft so as not to allow of any motion other than rotary, it will easily be seen that any turning moment acting on the shaft will tend to produce a pressure on the bearings equivalent to that moment divided by the length of the throw. As the action is repeated at every crank through which the turning moment is transmitted, each additional crank so placed as to be subject to distortion adds to the friction of the shaft. The assumption that the crank shaft is flexible while the bed plate is quite stiff is not correct, but the latter is probably in all cases stiffer than the shaft, and the pressure on the bearings is believed to be more than half of that which it would be if it were perfectly rigid. In the models the shafts have purposely been made with a great amount of elasticity in order to show better the effect described. One of the bearings is disconnected from the bed plate, and the motion imparted to it by turning the shaft is clearly seen. The direction of the motion depends upon the position of the cranks. If the bearing were quite free and the turning moment uniform, it would describe a circle about the true center line of the shaft during each revolution. Figs. 19 show a shaft in which two cranks are adjacent, and the throws equal and opposite with no bearing between them. In this case there is no appreciable tendency towards a displacement of the shaft. If the effect of the transmission of the turning moment of the high and intermediate pressure cylinders through the after pair of cranks be considered in detail, it will be seen that the bending of the web of the first crank, together with the twisting of the pin, tend to move a point in the center of the intermediate web from the true center line of the shaft; but the distortion of these parts in the second crank is equal in amount to that in the first, and therefore has the effect of preserving the shafting in a continuous straight line. All pressure upon the after bearings

due to distortion of the crank by the forward engines is therefore avoided.

The cylinders are unjacketed. There are a piston valve on the high-pressure cylinder taking steam in the middle and flat valves on the other three cylinders. The exhaust takes place through the back of the flat valves, and the directness of the passage is found to have an important effect upon the vacuum obtained in the low pressure cylinders. The indicator cards show a much better vacuum than that usually found in the case of high speed torpedo boat engines fitted with either piston valves or with D slide valves. The condenser is of rolled brass, with brass tubes through which water is circulated by a centrifugal pump assisted by a natural flow due to the velocity of the vessel. At all but the highest speeds this natural flow is sufficient of itself to maintain a vacuum. The air pump is single acting and is driven by the main engines. A Weir pump in the engine room, drawing from a feed tank common to both engines, returns the condensed water to the boilers. Auxiliary feed pumps are fitted in the stokehold.

The boilers are three in number and of the Thornycroft water-tube type. The total tube surface is 8,892 square feet. The heating surface, which is obtained by deducting from the total surface such parts of tubes as are not exposed to heat, is 7,890 square feet. The grate surface is 189 square feet. The boilers, Figs. 20, Plate 2, are not quite the same as those of H.M.S. *Speedy*, but have been modified in order to have two furnaces in each and to obtain a greater amount of fire grate in the available space. Three of the new *Daring* boilers are doing the work of eight in the *Speedy*. 23.3 I.H.P. is developed per foot of grate and 1.79 feet of heating surface are required per I.H.P.* The tubes are of steel and are galvanized on the outside. The products of combustion leave the fire box through openings between the tubes at the bottom of the inner wall, pass among the tubes and escape through openings between them at the top into the central flue, through which they find their way to the up-take

* The power taken is not the maximum, but the mean I.H.P. developed during a three-hours' trial.

and funnel placed at the end of the boiler. A row of down-take tubes of large diameter connects the upper and lower vessels.

The water level is automatically maintained at a constant height by means of a float in the upper vessel which regulates the opening of a valve in the internal feed pipe. The float being within the boiler, none of its moving parts require to work through stuffing boxes. It can in this manner be made more sensitive to small changes of water level. When stuffing boxes are employed, no movement of the float can take place until the change in its buoyancy due to a rise or fall of water is sufficient to overcome the friction of the stuffing box. Means are provided for altering from the outside the amount by which the valve is opened for a given position of the float; so that the quantity of feed admitted at any given water level can be adjusted to suit the rate of evaporation taking place at the time. This arrangement is shown in Figs. 21 and 22. It has acted well, and its introduction has greatly improved the working of the boilers in groups. With a steady water level automatically maintained, the stokers are able to fire with greater regularity and more steam can be made. No leakage has at any time occurred with these boilers; and since the float gear was fitted and the feeding thereby rendered steady, no priming has been experienced. In Appendix I is given a report by Prof. D. S. Capper upon a series of tests made by him with a model of the boiler.

The total weight of the boilers with water and mountings complete including up-takes, but without funnels, is 48.5 tons. The indicated horse power per ton of boiler is 91. The total weight of machinery and water, including spare gear, auxiliary machinery, funnels and up-takes is 115 tons, which is equivalent to 58½ pounds per horse power indicated by the main engines.*

Some difficulty was at first experienced with the propellers. A series of experiments carried out by the Admiralty upon the

* The weights of machinery include all items included in the tables given in the appendix to Durston on "The Machinery of War Ships," Minutes of Proceedings Inst. C. E., vol. cxix, pp. 32–46. Air compressors, steering and electric light engines, oil tanks, voice tubes and telegraphs in engine room, floor plates, ladders and gratings are classed as machinery.

torpedo gun boats had resulted in these vessels being fitted with narrow bladed screws, and the first screws of the *Daring* had the same ratio of developed area to disk area as those of the *Speedy*. The blades were of elliptical form, the minor axis of the ellipse being $\frac{4}{10}$ of the major axis. As the results obtained were very remarkable, the authors think it may be of interest if the screw trials are described in some detail. Three screws having the same amount of blade surface but varying slightly in diameter and pitch gave results of a similar character. Fig. 23 shows the curve of slip so obtained. The performances of the screws were so nearly alike that one curve only is shown for them, the points for each being marked 1, 2, 3, respectively. The slip was too great at all speeds, but at 22 knots per hour it commenced to increase very rapidly, rising to nearly 30 per cent. at 24 knots. The pitch of the screws was then somewhat reduced, and the result is shown in the slip curve marked 4. There was a decided reduction of slip at moderate speeds, but instead of becoming less at speeds above 25 knots per hour, as was expected, it continued to increase, and at $25\frac{1}{2}$ knots, which was the highest speed that could be obtained, it rose 23.7 per cent. The authors then arrived at the conclusion that the bad performance of the screws was due to the fact that too large a thrust was required from them per unit of area. The greater part of the acceleration of the screw race is produced by negative pressure on the forward side of the blades. If the whole thrust of the screw be divided into two parts, one part due to negative pressure on the forward side and the other to positive pressure on the after side, the negative exceeds the positive pressure in all cases except the limiting one in which no rotation is given to the race, a condition in which they become equal. The only force available for producing this acceleration in front of the screw is gravity. The recession of the helical surface as it revolves relieves the pressure of the water upon its forward face, and the water can only follow it up with the velocity which is due to the head above it. At the very small depth below the surface at which the screws work in the *Daring*, a few inches only, the weight of water over them may almost be neglected and the head

be taken as that due to the pressure of the atmosphere. 15 pounds per square inch is therefore the maximum thrust which can be obtained from the acceleration produced by atmospheric pressure close to the surface of the water. If the surface is broken and air admitted, the velocity which can be imparted to the water in advance of the screw is very small indeed, being limited to that due to the head of water above it. If it be assumed that six-tenths of the whole thrust is produced in front of the propellers of the *Daring*, then a negative pressure of 8½ lbs. per square inch of projected blade surface is required by No. 4 screws at 25½ knots per hour. The thrust at the center of the propeller is probably much less than at portions nearer the circumference, and it may well be that at the most effective part of the blades it approaches more nearly to a state of things in which the pressure is so low that cavities are formed behind the screw blades, filled with air and vapor boiled from the water. This view was confirmed by the very serious vibration of the stern which occurred when the engines were driven at full speed, although when the screws were removed the engines failed to shake the vessel when run at the same number of revolutions, showing that the vibration was caused by some irregular action of the propellers.

A pair of screws was made of the same diameter as No. 3 and of practically the same mean pitch, but having the blade surface increased 45 per cent. These gave a very satisfactory performance, as shown by the slip curve marked 6, Fig. 23, and no further changes were made. It will be seen that the slip is the same as that of No. 4 screws at about 19 knots per hour, but at higher speeds is much less. It reaches a maximum of 17¾ per cent. at 24 knots and then falls to 15¾ per cent. at 29¼ knots per hour. Comparing these screws with No. 3, from which they differ only in blade area, it will be seen that at 24 knots per hour the slip is reduced from 30 per cent. to 17¾ per cent., and the indicated horse power from 3,700 to 3,050. The number of revolutions per minute required to obtain 24 knots per hour with No. 3 gave 28.4 knots with No. 6. The excessive vibration also disappeared. The pitch of all the screws was variable, increasing from the leading to the following edge as is usual with Thornycroft screws. The slip is

measured from the mean of the pitches of the fore and after edges at the middle of the blade. The effective pitch of the wide bladed screws is somewhat greater than the mean thus obtained, that is, they do not turn so fast as screws of the same size but of uniform pitch equal to the nominal mean pitch. The slip curve of No. 6 exhibits a tendency to flatten at speeds above 27 knots per hour, and the authors are of opinion that these screws would break down in the same way as did Nos. 3 and 4, if pressed to a much higher speed. Above 28 knots or 29 knots per hour greater area is required. At 29¼ knots per hour the mean negative pressure, assuming it as before to be six-tenths of the whole thrust, is 7¼ pounds per square inch. "Cavitation," as Mr. Froude has suggested to the authors that the phenomenon should be called, appears to manifest itself when the mean negative pressure exceeds about 6¾ pounds per square inch, or when the whole thrust exceeds 11¼ pounds per square inch. This is with blades of elliptical form, but it will probably vary somewhat when the surface is differently distributed.

Results in strict accordance with those of the *Daring* were obtained contemporaneously from the trials of two torpedo boats. Nos. 91 and 92 are sister vessels and had screws of the same diameter and pitch, being made from the same drawing, but the surface of the screw of No. 92 was about 40 per cent. more than that of No. 91. At 24 knots per hour, the boat with the narrow blades required 16½ per cent. more power than the other, and the slip of the screw of No. 91 was 20 per cent., while that of No. 92 was 6 per cent. only. The negative pressure in the case of No. 91 is 9.8 pounds per square inch, and in that of No. 92 it is 6.72 pounds, the latter figure, it will be observed, agreeing very closely with that at which the screws of the *Daring* commence to fall off in efficiency, viz., 6.75 pounds. There seems to be more than a coincidence in these figures, and the results appear to show that a new condition of things has been entered upon. The analysis of the speed trials of a number of vessels built at Chiswick shows that in no previous case has the negative pressure exceeded 7 pounds per square inch except in No. 93 torpedo boat and in the *Speedy*, where it amounted to 7.9 pounds and 7.4 pounds respect-

ively, and it is probable that in No. 93 the blade area is too small. The vessel passed out of Messrs. Thornycroft & Co.'s hands before the experiments described had taken place, or wider bladed screws would have been fitted and tried.

The surface used in these calculations is the projected surface, because the thrust dealt with is sternward only. The improvement obtained with No. 4 screws at moderate speeds as compared with Nos. 1, 2 and 3 was probably due to the greater projected area obtained by twisting the blades to a finer pitch. More developed blade area is required for screws of great pitch ratio than for those in which the pitch ratio is small; because the projected area of a given screw is inversely proportional to the pitch ratio, and also because the ratio of negative to positive pressure becomes greater as the pitch ratio is increased.* Mr. Normand has described what he calls the rupture of the column which occurs when air finds its way from the surface to the screw. He made some experiments with a moored vessel and ascertained the thrust obtainable with different immersions; but he dealt only with the case of free communication between the atmosphere and a screw or rudder by vortices or otherwise, when rupture takes place as soon as the speed at which the water is required to fill the void behind the propeller or rudder exceeds 14.5 feet per second or $8\frac{1}{2}$ knots per hour, at a depth of 1 meter.

It is apparent that if the authors' reasoning is correct, the speed of vessels has now approached within measurable distance of that at which propulsion by screws depending upon the reaction of water, becomes inefficient. For a given pitch ratio and slip, *i. e.*, at what is known as "given abscissa value," the thrust per unit of area varies as the square of the speed. Since the total thrust required to propel a ship at a given speed is a fixed quantity depending upon the resistance, it follows that cavitation can only be avoided at very high speeds, or, to be more exact, at speeds such that the critical ratio of thrust to area is reached, by increasing either the immersion of the screw or its blade area. The immersion is usually governed by considerations of draught of water; and, provided it is sufficient to prevent air from penetrat-

* Minutes of Proceedings Inst. C.E., vol. cii, p. 87.

ing from the surface, it is not practicable to obtain much benefit by lowering the screw. Increased blade area may be obtained in three ways. 1st. By increasing the ratio of blade area to disk area. 2d. By reducing the abscissa value, or, in other words, employing a larger diameter of propeller working at less slip than that theoretically best for the given conditions. 3d. By increasing the pitch ratio, which involves a larger diameter with a reduced rate of revolution. Either course tends to a waste of power if pursued beyond somewhat narrow limits, and it appears inevitable that reduced efficiency must be submitted to as the speed of vessels is increased.

APPENDIX.

TESTS OF A MODEL THORNYCROFT BOILER.

ENGINEERING LABORATORY, KING'S COLLEGE, LONDON,
15th March, 1895.

MESSRS. J. I. THORNYCROFT & Co., Chiswick.

Dear Sirs: I have made a series of tests with the model boiler which you sent to me for trial, and have determined its efficiency for eight different rates of steaming at atmospheric pressure. The boiler with four rows of water tubes each side and a total heating surface of 12.4 square feet contains 4.1 pounds of water up to datum level. Gauge marks were placed at each end of the steam drum and the water level sighted from end to end through the glass plates with which it was provided. In this way the level could be determined with great accuracy. With one exception the trials lasted for over half an hour; observations of gas and feed water with feed and funnel temperatures being taken every five minutes.

Gas.—The gas was measured by a standard gas meter made by Messrs. Alex. Wright & Co., which has been tested and certified correct by the Standards Department of the Board of Trade. This identical meter was used on the Society of Arts motor trials, and has a dial which can be read to the $\frac{1}{100}$ cubic foot. The pressure is measured by an ordinary water gauge, and the temperatures of both inlet and outlet by standardized thermometers.

Water.—The feed was supplied from the rectangular copper tank accompanying the boiler. For measuring the quantity used, a float was provided graduated in pounds and half-pounds. By subsequent calibration I have found these graduations correct. Throughout each trial the level of the water in the boiler was maintained as nearly constant as possible, special care being taken that it should be brought to the datum line at the end of each five minutes' interval when the observations were taken.

Temperatures.—The feed and funnel temperatures were measured on thermometers which have recently been standardized in my laboratory. The feed water was allowed to stand for some time before use in buckets close to the boiler, so that its temperature was very steady at that of the room. The temperature of funnel gases was measured at the hottest point just below the level of the top of the steam pipe.

Efficiency.—For calculating the boiler efficiency the thermal value of the gas has been assumed equal to 19,000 B.T.U.'s per pound. This is the mean thermal value obtained from a number of analyses recently made for me by Mr. G. N. Huntly. Individual values did not differ from this mean by 2 per cent. in any case, although an interval of more than a year elapsed between the first and last observation. From the same analyses the value of K (difference between Kp and Kv) was determined $= 130$, and this value has been used for the calculation of the specific volume of the gas. For this purpose the temperature and pressure at the meter were observed during each test and the corresponding specific volume of the gas found.

The first trial made without any funnel gave such anomalous results that a funnel 10 inches high was added for the subsequent experiments. Without a funnel the efficiency was only 38.8 per cent. when burning over 70 cubic feet of gas per hour.

It was incidentally found that any sudden variation in the rate of feed made a very marked reduction in the evaporation, and consequently in the efficiency. An accidental lowering in the water level at the time of refilling the feed tank made a rapid addition of feed necessary to bring the water in the boiler up to datum level in time for an observation to be made. It was found that the evaporation during the subsequent five minutes was

reduced to exactly one-half its mean value for the rest of the trial. This point was therefore carefully watched, with the result that any considerable irregularity of feed was invariably found to be accompanied by a perceptible slackening of the violence of ebullition, and, if aggravated, by a diminution in the rate of evaporation during the following interval.

The results of the experiments have been plotted on a base representing rates of transmission per square foot of heating surface. It will be noticed (Fig. 24) that the line joining the tops of the ordinates representing efficiencies per cent. is very closely a fair curve. The efficiency increases in value as the rate of transmission is increased up to a maximum value of 86.8 per cent. when the rate of transmission is 22.35 B.T.U.'s per square foot per minute. It then gradually decreases in value until a rate of transmission of nearly 39.5 B.T.U.'s per square foot per minute is reached, when the efficiency is 68 per cent. From this point the efficiency very rapidly falls off, showing that the air supply is not sufficient for the perfect combustion of the gas. Some means for artificially increasing the air supply would be beneficial beyond this point.

A very valuable fact, which is for the first time shown by these experiments, is that the economy of model boilers may be under certain conditions as great as that of full sized boilers of the same type. In some trials made by Prof. Kennedy, and recorded in the Minutes of Proceedings of the Institution of Civil Engineers, Vol. xcix, session 1889–'90, a precisely similar efficiency of 86.8 per cent. was obtained with a Thornycroft boiler having 1,837 square feet of heating surface at a rate of transmission of 23.8 B.T.U.'s per square foot heating surface per minute. Should this comparison prove capable of general application, very considerable advantage might be derived from model boiler experiments.

A table showing the results of the eight trials is appended; and a diagram giving the efficiency curve, quantities of gas used, and water evaporated for different rates of transmission (Fig. 24) is also added.

I am, Gentlemen, yours faithfully,

D. S. CAPPER.

TABLE.

Date.	Feb. 26.	Feb. 26.	Feb. 25.	Feb. 25.	Feb. 25.	Feb. 26.	Feb. 28.	Feb. 28.
Duration (minutes)	45	50	30	45	40	50	20	30
Atmospheric pressure (lbs. per square inch)	14.67	14.71	14.66	14.66	14.66	14.64	14.75	14.77
Meter pressure (lbs. per square inch)	14.74	14.78	14.73	14.73	14.72	14.71	14.82	14.88
Gas per hour (cubic feet)	12.01	19.69	31.9	46.3	55.2	70.98	81.8	101.84
Gas per hour (lbs.)	0.385	0.633	1.01	1.47	1.77	2.27	2.60	3.25
Thermal equivalent at 19,000 B.T.U. per lb.)	7,315	12,030	19,190	27,930	33,630	43,090	49,320	61,690
Equivalent in lbs. of water per hour from and at 212° F.	7.58	12.45	19.82	28.91	34.8	44.6	51.06	63.85
Temperature of feed (°F.)	48.0	48.0	52.0	51.0	43.0	48.0	46.5	52.5
Factor of evaporation	1.170	1.170	1.165	1.167	1.175	1.17	1.171	1.165
Feed water (lbs. per hour)	4.2	8.34	14.79	20.4	22.8	25.92	27.00	28.392
Equivalent from and at 212° F.	4.91	9.76	17.23	23.81	26.96	30.33	31.62	33,084
Temperature of funnel gases (° F.)	.....	.....	228	238	220	227	252	245
Heating surface (sq. feet)	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Water evaporated in lbs. per square foot of heating surface per hour	0.338	0.675	1.195	1.64	1.85	2.09	2.1	2.29
Mean rate of transmission of heat (B.T.U. per sq. foot heating surface per minute)	6.475	12.66	22.35	30.9	35.0	39.38	41.05	42.95
Efficiency of boiler (per cent.)	64.7	78.5	86.8	82.2	77.5	68.0	61.9	51.8

In the discussion which followed the reading of this paper, Mr. Yarrow gave the following particulars of the progressive trials of the *Hornet*, the displacement being 220 tons:

Speed, knots, . .	11.3	16.7	23.4	27.6
I.H.P., . . .	207	1,200	2,700	3,884

The propellers were 6 feet 6 inches in diameter and had a uniform pitch of 8 feet, and a total developed area of about 1,700 square inches. In the *Hornet*, the maximum speed was obtained with a slip of 11 per cent., and in the *Havock*, a maximum speed of 26.5 knots, with 9 per cent. slip.

Prof. D. S. Capper observed with reference to the series of trials which he had made with the model Thornycroft boiler exhibited, that it had at first been intended merely to determine the efficiency of the model so as to compare it with a full sized boiler of the same type. The boiler had a heating surface of 12.4 square feet, and when filled to working level contained 4 pounds of water. A complete report of the trials with a table of

the results was given in the appendix to the paper. One of the first trials made was that given in the third column of the table. With a mean rate of transmission of 22.35 British thermal units per square foot of heating surface per minute, the water evaporated per square foot of heating surface per hour was 1.195 pounds, and the efficiency was 86.8 per cent. On comparing this with the trials made by Dr. A. B. W. Kennedy on a Thornycroft boiler having 1,837 square feet of heating surface, with a rate of transmission of 23.8 British thermal units per square foot heating surface per minute, and water evaporated equal to 1.24 pounds per square foot of heating surface per hour, it appeared that the same efficiency had been obtained. This result was so striking that a series of trials at progressive rates of steaming had been carried out. The trials were all conducted at atmospheric pressure, the arrangements not being such as to permit of working at high pressures. It might also be pointed out that there was no means at hand for artificially increasing the air-supply, and consequently the rate of transmission of heat, *i. e.*, the rate of steaming, could only be increased by increasing the gas supply. He thought the result of that would clearly be seen in the efficiency curve, Fig. 24. The 100 per cent. efficiency line was shown on the diagram, and the curve crossing it showed at each rate of steaming the efficiency as compared with perfect efficiency; starting with a rate of transmission of 6.4 British thermal units per square foot per minute, an efficiency of 64.7 per cent. was obtained, from which point the curve rose gradually up to its maximum value, 86.8 per cent. as already stated. After the maximum was reached, the efficiency decreased more and more rapidly until at a rate of transmission of 42.95 British thermal units per square foot per minute, it was 51.8 per cent. In Dr. Kennedy's trials that fall was not nearly so rapid, for at a rate of transmission of 158 British thermal units per square foot per minute he had obtained an efficiency of 66.6 per cent. This divergence was most probably due to the incomplete combustion of the gas in consequence of deficient air supply in the experiments with the model after the maximum point had been reached. There were distinct signs that this

was taking place during these trials. He thought it was highly probable that if experiments were carried out with a properly arranged artificial air supply, the curve of model efficiencies would approach much more closely at its latter end to that of the full sized boiler.

The first part of the curve was the most interesting and important, and clearly showed that in this case at least, experiments with a model having less than 12½ square feet of heating surface were comparable with the results obtained with a boiler having a heating surface nearly 150 times as great. The thermal value of the gas used had been taken as 19,000 British thermal units per pound, this being the average of a number of analyses made by Mr. G. N. Huntly. These analyses differed little, although the samples were taken at long intervals—the last of them within a month of the trial. He thought that value could be adopted as accurate, although the gas was not analyzed during the trials. Taking that figure, 1 pound of gas was equivalent in heating value to 1.32 pounds of carbon; and at its maximum efficiency the model boiler therefore evaporated 13.02 pounds of water from and at 212° F. per pound of carbon value. That was a remarkable result in a boiler of the size referred to, and seemed to indicate that the type of boiler under consideration was as efficient on a small as on a large scale.

It had been pointed out by the authors that they had invariably found when the speed of the engine exceeded a certain amount, the power seemed to be underlogged. It was a very interesting matter, which called in question the accuracy of the indicator. He would like to hear how far it was found that the power was underlogged, or that it was suspected of being underlogged. It was difficult to carry out experiments with an indicator in such a way as truly to compare its indications with any scientific standard when running at a high speed, and thus to determine its errors under working conditions. He had made a number of experiments bearing on that point on an apparatus he had devised for the purpose. A steam cylinder was suitably connected with a mercurial column so that pressures in the cylinder could be read directly in inches of mercury. He had found that if the

pressure was suddenly applied by opening the cock of the indicator, the pressure recorded by the latter was invariably less than the true pressure as shown on the column. And that this difference was not due to any drop in the pressure of the steam cylinder on opening the indicator cock, was shown by the indications of a gauge attached to the cylinder. He was aware that gauge readings were not to be relied on for absolute readings; but for checking differences of pressure they could be made to all practical requirement reliable. Those results seemed to point in the same direction as the underlogging of power recorded by the authors, but his experiments, though extensive, were not sufficient in number and range to warrant him in asserting definitely that similar results would always be obtained. He thought the authors were to be congratulated on having pointed to a limit being possibly obtained, in one direction at least, in the complicated problem of propellers; and the results which had been shown in connection with cavitation were extremely interesting and valuable.

Fig: 1.

H. M. TORPEDO-BOATS "41" TO "60" ETC.

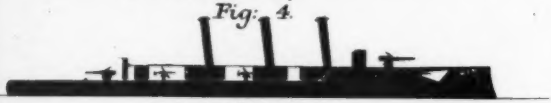
Fig: 2.

H. M. S. "DARING."

Fig: 3.

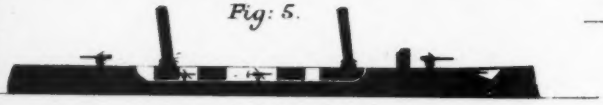
H. M. S. "RATTLESHAKE".

Fig: 4.

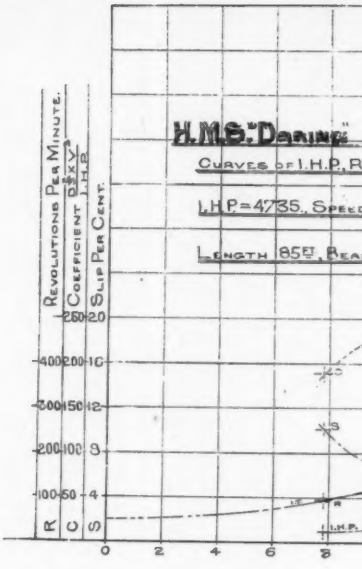


H. M. S. "SPEEDY."

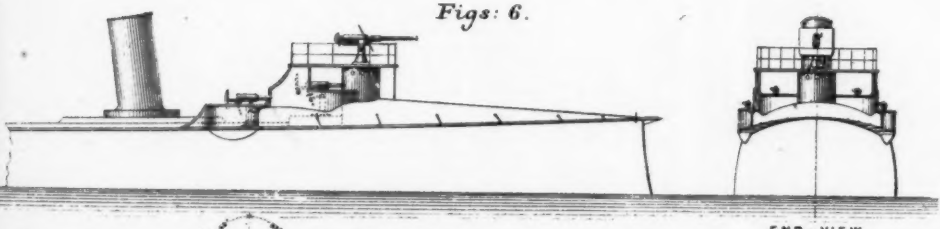
Fig: 5.



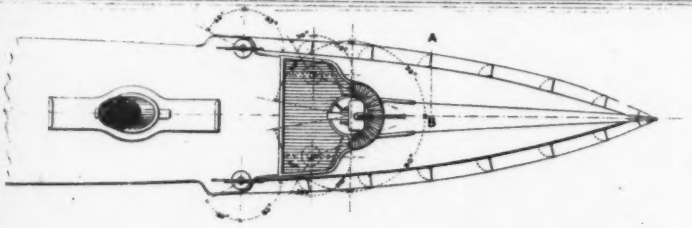
H. M. S. "HALCYON".



Figs: 6.

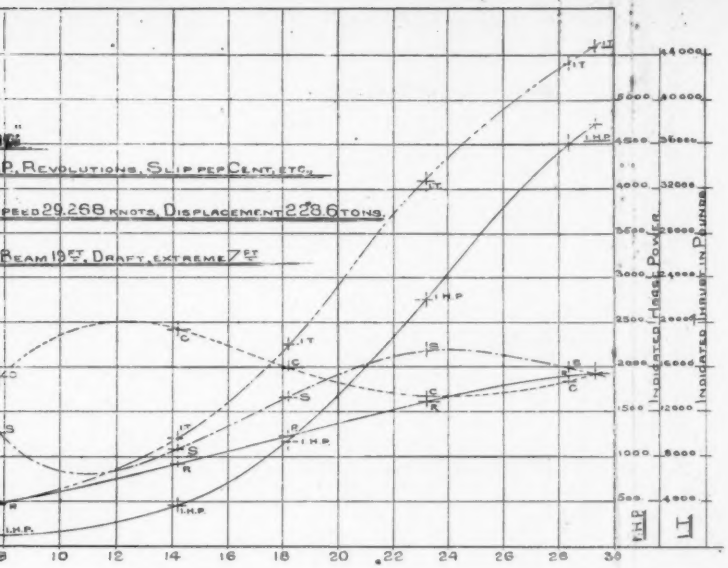


END-VIEW



SECTION AT A.B.

FIG. 7.



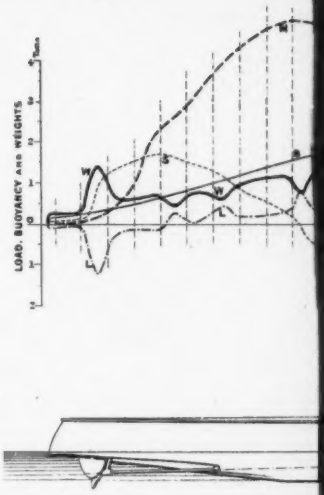
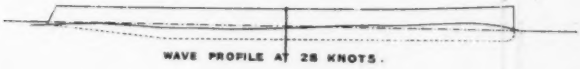
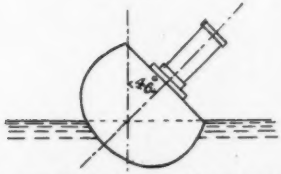


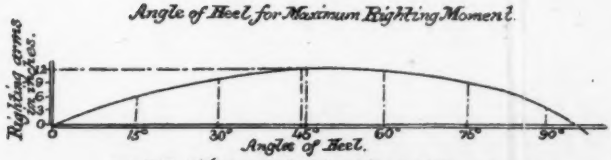
Fig. 8.



Figs. 9.

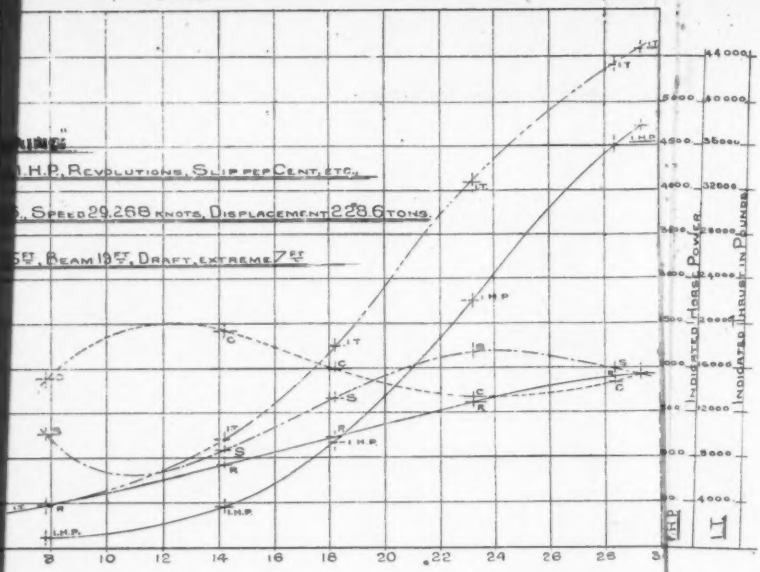


Angle of Heel for Maximum Righting Moment.



H. M. S. 'Darling'— Stability Curve.

FIG. 7.


I.H.P, REVOLUTIONS, SLIP PER CENT, ETC.,
SPEED 29.268 KNOTS, DISPLACEMENT 2286 TONS.
BEAM 19FT, DRAFT, EXTREME 7FT
INDICATED HORSE POWER
INDICATED THRUST IN POUNDS
I.H.P.
8 10 12 14 16 18 20 22 24 26 28 30

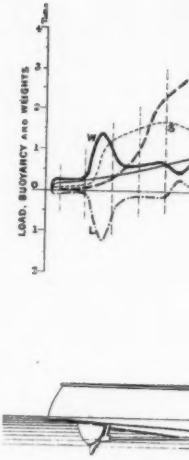
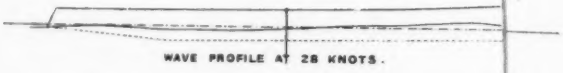
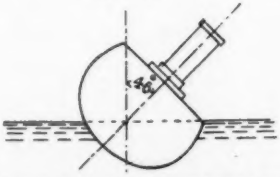


Fig. 8.

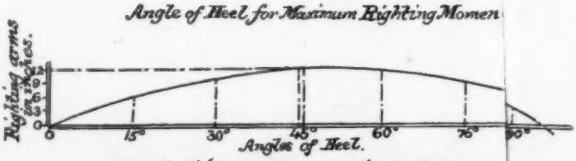


ON AT A.B.

Figs. 9.

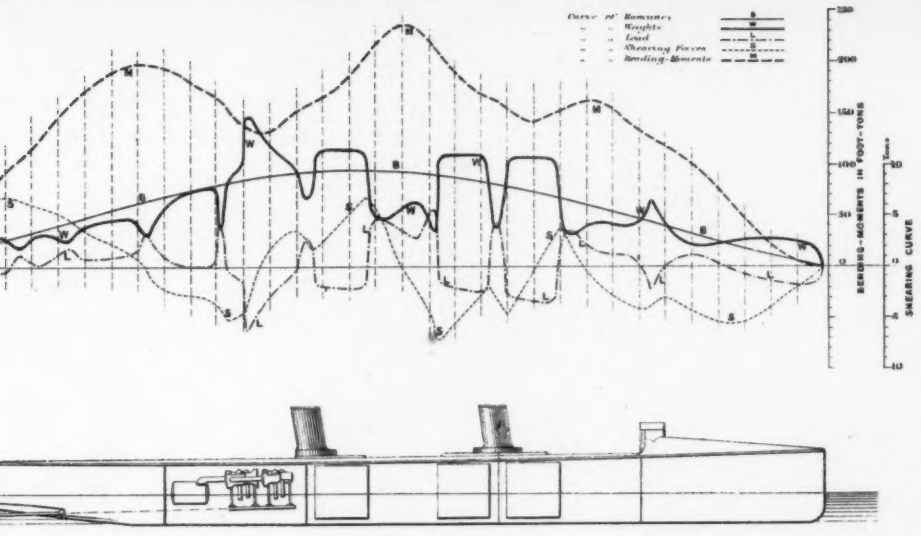


Angle of Heel for Maximum Righting Momen



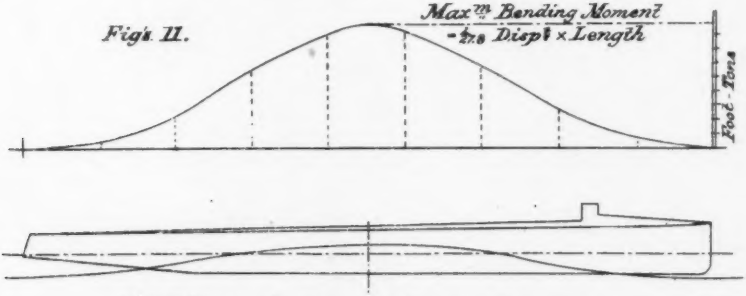
H. M. S. 'Darling'— Stability Cu

Figs. 10.



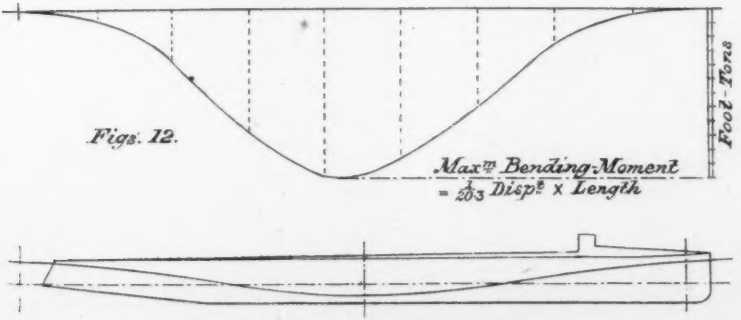
Scale for Figs. 10. 1/72nd Inch to 1 Foot.

Figs. 11.



H.M.S. 'Daring'— Curve of Hogging Moments.

Figs. 12.



H.M.S. 'Daring'— Curve of Sagging Moments.

Figs: 13.

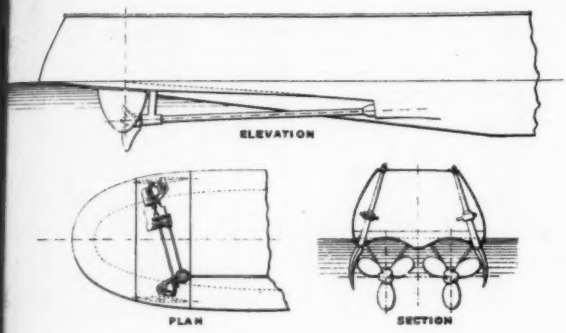


Fig: 14

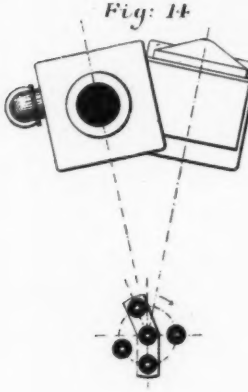
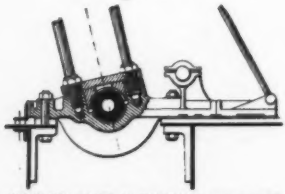
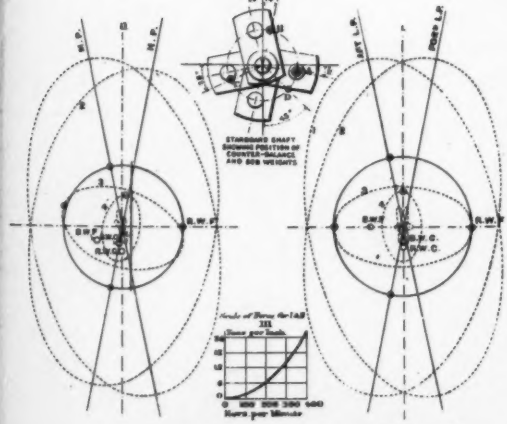


Fig: 16.

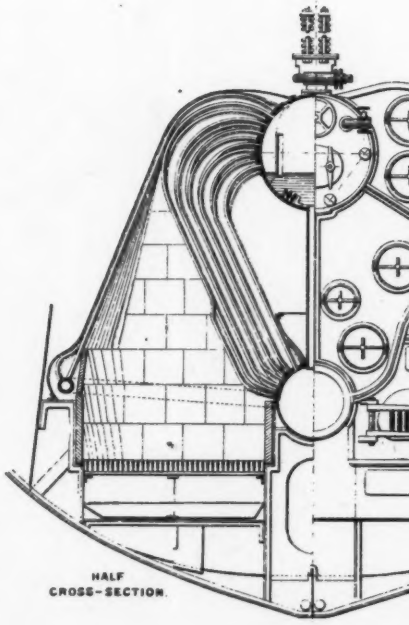


ENLARGED SECTION THROUGH BEDPLATE

Figs: 17.

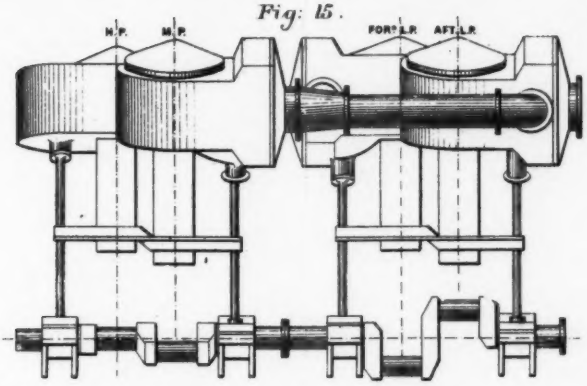


INERTIA DIAGRAMS FOR ENGINES OF H.M.S. "DARING"



HALF CROSS-SECTION.

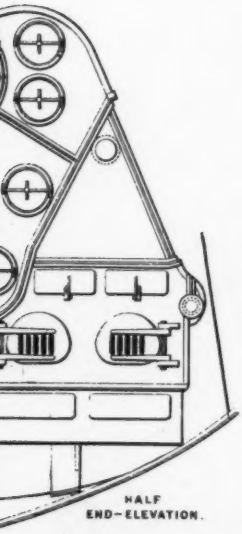
Fig: 15.



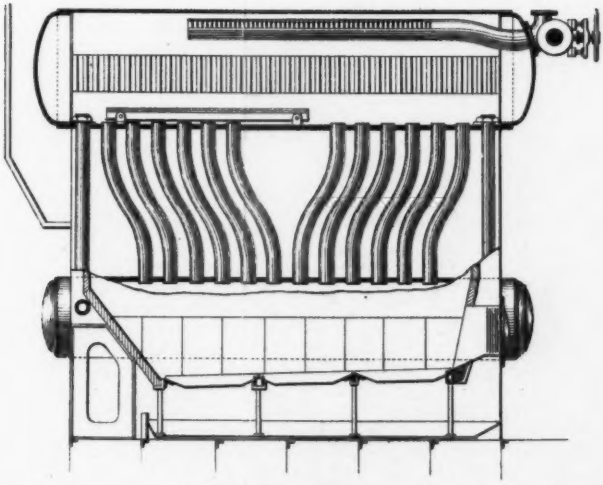
ENGINES OF H.M.S. "DARING".

Effect o

Figs: 20.



HALF
END-ELEVATION.



LONGITUDINAL SECTION.

BOILERS OF H.M.S.

Fig: 14

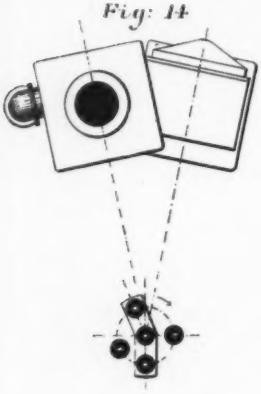
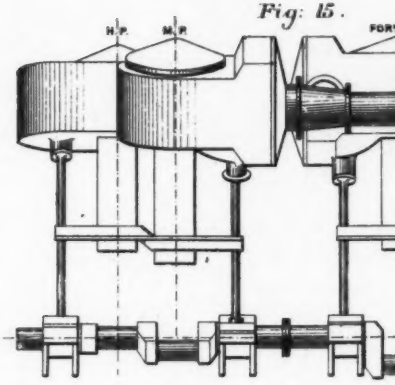
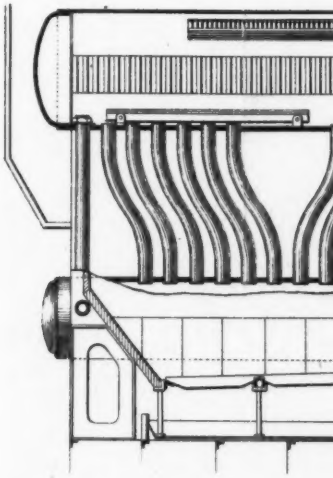


Fig: 15.

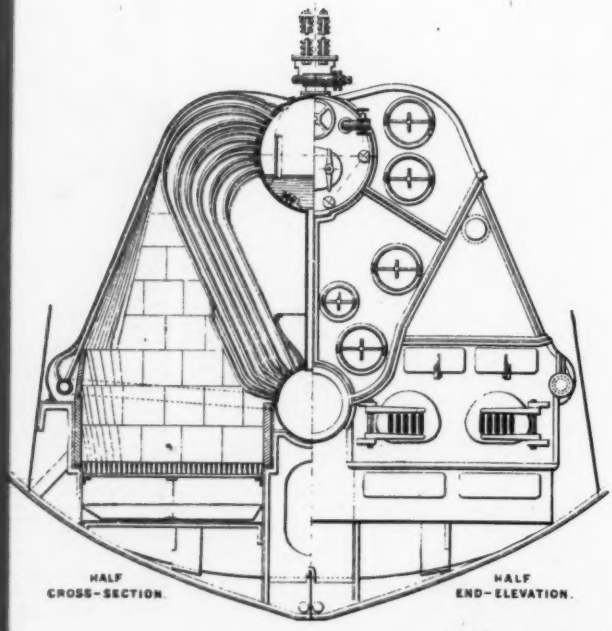


ENGINES OF H.M.S. "DARING".

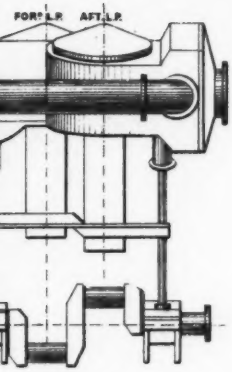
Figs: 20.



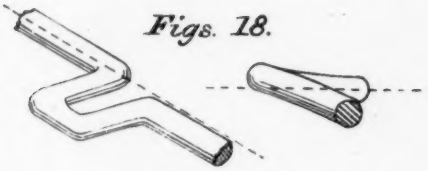
LONGITUDINAL SE



BOILERS OF H.M.S.



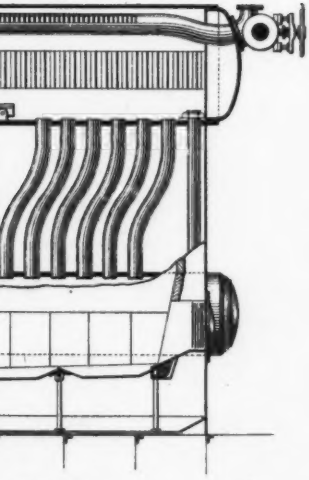
Figs. 18.



Figs. 19.

Perspective View. *End View.*

Effect of Torsion upon Shafts with Single and Double Throw-Cranks.



SECTION.

Fig: 21.

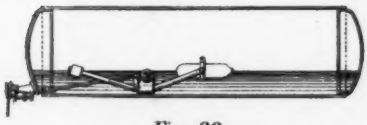
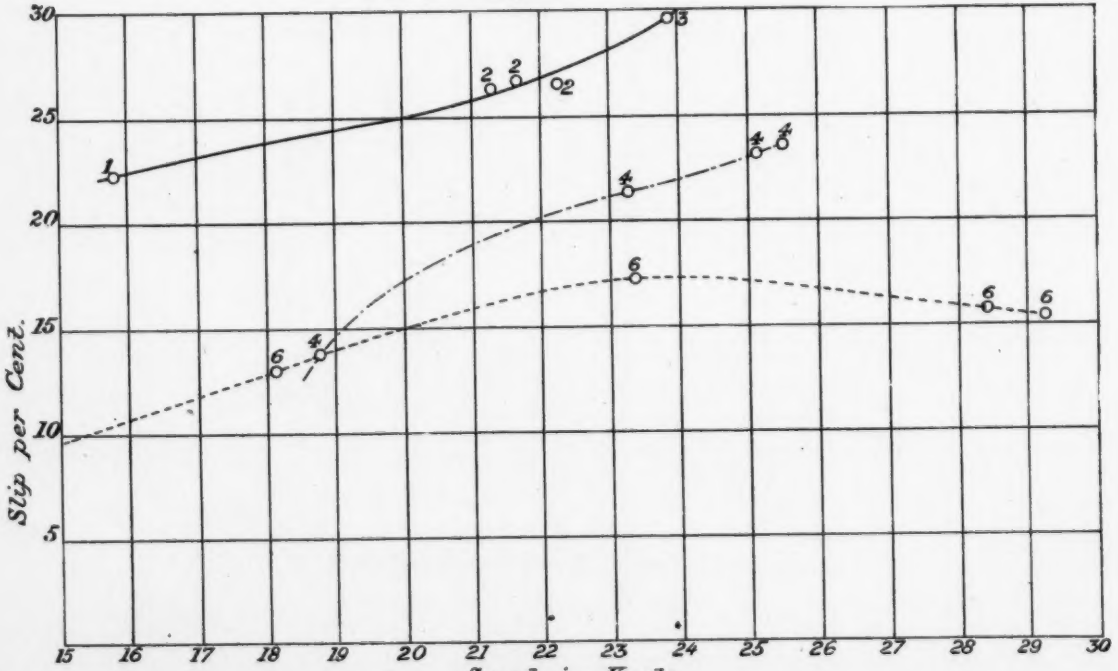


Fig: 22

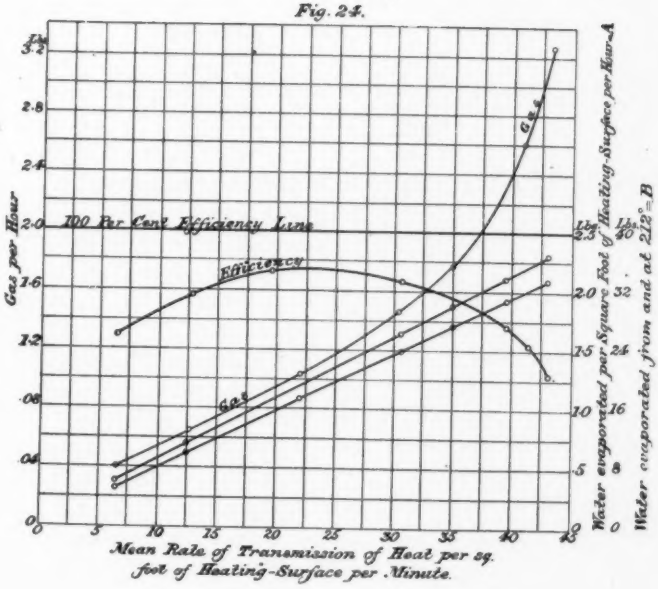
ENLARGED SECTION THROUGH VALVE

Fig. 23.



H.M.S. 'Daring'—Curves of Slip per Cent of Propellers.

Fig. 24.


Gas per Hour
100 Per Cent Efficiency Line
Efficiency
Gas
Water evaporated per Square Foot of Heating-Surface per Hour=A
Water evaporated from and at 212°=B
Mean Rate of Transmission of Heat per sq. foot of Heating-Surface per Minute.

EXPERIMENTS TO DETERMINE THE CAUSES OF STEAM PIPE EXPLOSIONS ON BOARD GERMAN NAVAL VESSELS.

CONDUCTED AT THE ROYAL DOCKYARD, WILHELMSHAVEN, AND REPORTED IN THE "MARINE RUNDSCHAU."

TRANSLATED BY WM. WACHSMANN, ESQ., ASSOCIATE.

The frequent bursting of steam pipes has led to the investigation of the causes of these accidents.

In most cases the explosion has taken place while admitting steam into the pipe system, as for instance on H. I. M. S. *Siegfried*, March 18, 1892; on H. I. M. S. *Wacht*, June 20, 1889; on H. I. M. S. *Prinzess Wilhelm*, August 9, 1891; on the same ship on November 7, 1893, when a stop valve in the main steam pipe exploded; in a boiler plant at Ferranti's, Deptford, England, July 9, 1889; on the S. S. *Jumma*, December 13, 1890; in a boiler plant of the new mill in Zuellichan, near Stettin, Germany, in 1860, etc.

From these examples the supposition arose that possibly water, contained in the pipes, caused water hammer. On this supposition, the following tests were made.

I. PREPARATION FOR THE TESTS.

(*a.*) *Arrangement of the first experimental pipe.*—A pipe was taken consisting of 2 lengths, each 6.5 feet long, 5.9 inches inside diameter, and 0.197 inch thick, and the ends tightly closed by flanges. To one of these flanges a .7874-inch stop valve was bolted in such a manner that the lower edge of the hole of the valve was in line with the inner side of the pipe, so that when the

pipe was put in proper position the steam would enter at the lowest point.

To the other flange on the pipe a blow off or water drain cock 0.4724 inch in diameter was secured, and in the center of this same flange, a high pressure gauge (registering to 2,133 pounds) with a maximum hand. Vertically above the drain cock an air cock was fitted so that water could be blown off at the lowest and air at the highest point of the experimental pipe. Later, a second pressure gauge was placed on the upper side of the pipe 22.83 inches from the flange containing the steam inlet valve.

The stop valve on the experimental pipe was connected by a 0.7874-inch pipe to a valve in the main steam pipe of the machine shop boiler, which carried a pressure of 70 pounds. The experimental pipe was inclined upwards from the steam inlet valve, so that if any water were present the steam would have to pass through it.

(*b.*) *Arrangement of second experimental pipe and its alterations.*—The second pipe was made up of parts of the old steam pipe of the hulk *Bismarck*. It consisted of three pieces 12.2 inches in inside diameter and about 0.236 inch thick. Attached thereto were four maximum pressure gauges, capable of registering to 2,133 pounds, an air cock, and a water drain cock, 0.7874 inch in diameter, as shown in Fig. 1.

This pipe was then connected by a pipe, 3.15 inches in diameter, with the main steam pipe of the machine shop, a 3.15-inch valve being inserted near the main steam pipe.

The first change in this pipe, which is shown in Fig. 2, was the removal of that part of the pipe which was bent upwards and the insertion of a 1.97-inch stop valve to connect with the 3.15-inch pipe.

After the bursting of this pipe near the flange opposite the steam inlet, and after the steam gauge on this flange had been destroyed for the second time, the damaged part of the pipe was cut off, the flange brazed on again, and the blank flange again secured in place minus the pressure gauge. The pressure gauge III was then placed near this flange on the side of the pipe.

This second change is shown in Fig. 3.

II. PROGRAMME OF THE TESTS.

1. Pipe *without* water, air cock closed and the drain cock open.
2. Pipe *without* water, air cock open and the drain cock closed.
3. Pipe *without* water, air and drain cocks open.
4. Pipe *without* water, air and drain cocks closed.
5. Vacuum in pipe and *some* cold condensed water formed by creating vacuum, air and drain cocks closed.
6. Vacuum in pipe, and the latter *filled with water* to about one-third of its cubic capacity, so that the point where the steam entered was under water in the first pipe, it being made to incline towards that point. In the second pipe the water filled that part of the pipe as indicated by the shaded surface. Air and drain cocks were closed.
7. Pipe *without* vacuum *filled with water* as under 6, air and drain cocks closed.
8. Pipe *without* vacuum *filled with water* the same as under 6, air and drain cocks open.

III. METHOD OF MAKING AND RESULTS OF THE TESTS.

(*A.*) *With the first pipe.*—Steam was admitted to the pipe to be tested by rapidly opening the stop valve on the main steam pipe of the boiler, the influx of steam having been regulated beforehand by adjusting the stop valve on the flange of the experimental pipe. Beginning with one fifth of the area of this valve, the opening was increased one-fifth in each of the succeeding tests.

In order to get reliable results, the eight tests in the programme were repeated several times with the same valve opening.

In carrying out tests 1 to 4 no hammering in the pipe or motion was observed, whether the filling of the pipe with steam was retarded or accelerated. The pipe became heated, slowly or quickly, according to the rapidity with which it filled with steam, until it became thoroughly warmed and the pressure gauges on the pipe indicated the steam pressure in the boilers.

As soon as a vacuum formed and a small amount of condensed water was present in the pipe (Test No. 5), light hammering was observed when steam was admitted; this was not, however, indicated on the pressure gauges but caused only a slight movement

of the pipe. This hammering and the backward and forward movement of the pipe became more intense, the greater the quantity of water present (Tests Nos. 6 and 7), manifesting itself in distinct blows and at shorter intervals and causing the maximum hands of the gauges to indicate different pressures varying between 128 and 242 pounds.

Whether the vacuum in the pipe (Test No. 6) had any influence on the action of the steam when it was admitted, could not be determined by any of the trials.

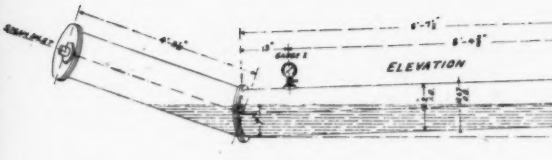
The heaviest hammering as well as the greatest movement of the pipe, which also continued for some length of time, were observed when the pipe was about one-third full of water and both air and drain cocks kept open (test No. 8), and for all five openings of the valve.

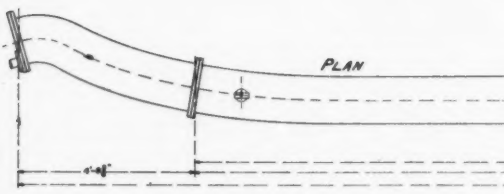
During these tests, there was a uniform discharge of water from the drain cock and of air from the air cock, for a longer or shorter time (depending on the opening of the stop valve in the pipe), and the accompanying forcible hammering.

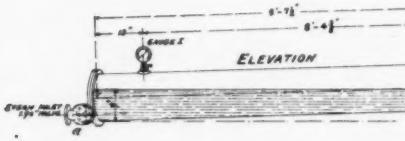
For instance, with $\frac{1}{5}$ opening of stop valve the first hammering was noticeable after 4 minutes; at $\frac{3}{5}$ opening, after 30 seconds; and 15 seconds after the valve was wide open, powerful hammering and violent motion of the pipe set in; in each case accompanied by an impulsive discharge of water and air and later by steam from the air and drain cocks. These phenomena are due to the fact that the steam is condensed by the water present, and only when the water has attained the temperature of the steam does the impulsive action of the latter set in.

The pressures observed on the gauges at the end of each trial (test No. 8) fluctuated between 284.5 and 1,066.75 pounds. At one time the greatest pressure would be observed on the gauge tapped in the flange, and then on the one attached to the side of the pipe.

(*B.*) *With the second experimental pipe.—a. According to the first arrangement.*—To establish the action of steam in bent piping of large diameter, the same tests as above were made with the second experimental pipe, arranged as shown in Fig. 1. Steam from the 3.14-inch supply pipe was admitted into that part of the pipe which was inclined upwards.


ELEVATION


PLAN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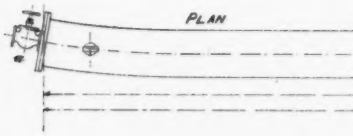
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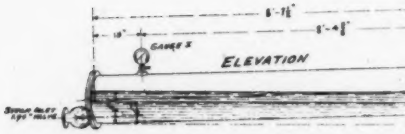
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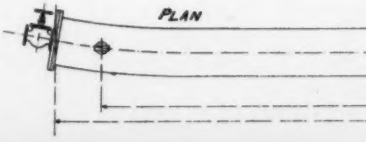
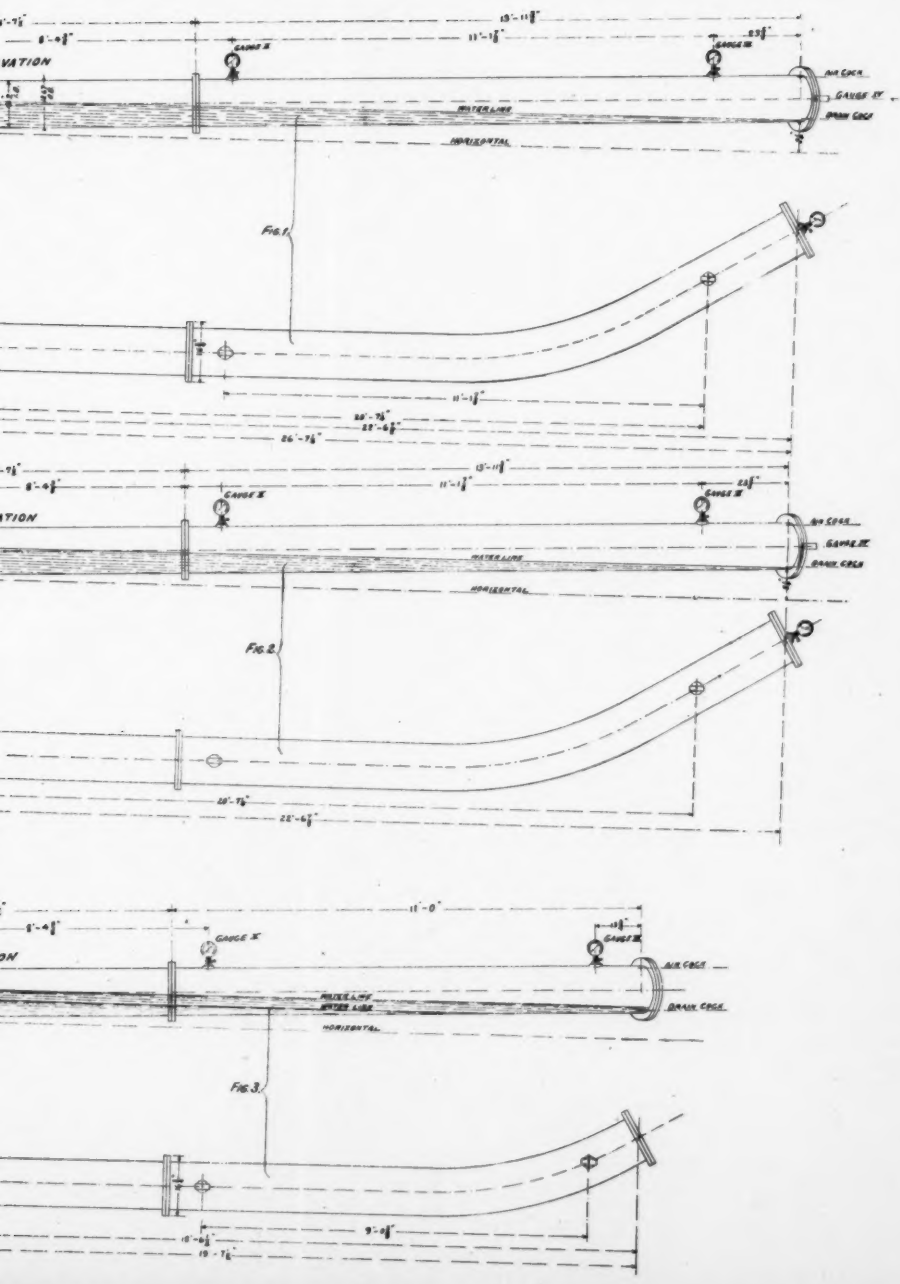

PLAN

TEST PIPE II.


GAUGE II
GAUGE III
AIR COCK
GAUGE IV
DRAIN COCK
WATER LINE
HORIZONTAL
FIG. 1.
FIG. 2.
FIG. 3.

In testing the pipe when empty, with or without vacuum, the same observations as before were made.

When the pipe was $\frac{1}{3}$ full of water as indicated by the shading in the sketch, the action of the steam was entirely different from that observed in the first experimental pipe. Only single blows occurred in the pipe, which were insignificant in comparison with those observed in the first pipe.

The greatest pressures observed in any of these tests, the cocks being open and steam admitted suddenly, was 426.7 pounds on gauge I, 113.7 pounds on gauge II, 199 pounds on gauge III, and 113.7 pounds on gauge IV. In opening the stop-valve slowly, the hammering was so insignificant that the maximum pressures indicated on all the gauges at the end of the tests was the same as the boiler pressure. The great difference in the results of these tests and those with the first pipe, suggested a modification of this pipe according to the arrangement shown in Fig. 2.

b. According to the second arrangement.—The same general results were obtained as with the first experimental pipe for the 8 tests of the programme and with the different openings of the stop valve, the only difference being that the intensity of the hammering in some of tests caused accidents, which, in some instances, resulted in breaking the new heavy ropes which were used for holding the pipe.

On August 14, when the stop valve was $\frac{3}{5}$ open, the pipe being filled with water, as shown in the sketch, and with the air and drain cocks open, the threads of four nuts on the securing bolts in the end flange were sheared off, the flange itself was much bent, the gauge tapped into it destroyed, and the pipe in the neighborhood of this flange bulged outwards. The pressure shown by gauge I was 483.5 pounds, by gauge II, 384 pounds and by gauge III, 924.5 pounds.

On August 22, with $\frac{3}{5}$ opening of the stop valve, and after the steam had been turned on for 65 seconds, the pipe burst 3.9 inches from the end flange for a length of 8.26 inches. The pressures in this case were 313 pounds on gauge I, 185 pounds on gauge II, 853.3 pounds on gauge III, while the limit of 2,133 pounds was exceeded on the gauge in the flange. After this

accident the damaged portion of the pipe was cut off and the repaired pipe used for further tests.

c. According to third arrangement.—The same observations were made as with the first pipe and the arrangement *b* of the second pipe.

To determine at what water level violent hammering takes place, the height of water was gradually diminished by stages, 1.18 inches, 0.78 inch and 0.39 inch, until it reached the line shown in Fig. 3 (6 inches deep at the steam inlet end). At this level, motion of the pipe was still observed, but the hammering had nearly ceased, so that it had no effect on the gauges.

At a level of 6.69 inches, the hammering was still so very violent that the maximum pressures observed, September 25, were, on gauge I, 853.3 pounds; gauge II, 497.8 pounds; gauge III, 853.3 pounds; and, October 3, on gauge I, 568.9 pounds; gauge II, 497.8 pounds; whilst the screw tap on gauge III was torn off.

By increasing the original water level of 9 inches to 9.84 inches, measured at the flange where the steam entered, the two bolts vertically opposite each other in the end flange were broken and the first section of the pipe near the intermediate flange ruptured by two splits, 2.3 and 3.9 inches long. After this, the pipe was useless, and no further tests were made.

In none of the tests could the water in the pipe be entirely ejected, even after a long period of blowing off and after the pressure had fallen to that in the boiler. In most of the cases, the water level was 3.14 inches high, measured at gauge I.

IV. DEDUCTIONS FROM THESE TESTS.

As a result of these tests, it is shown that destruction of a completely drained, although entirely cool, pipe cannot occur, whether the stop valve near the boiler under steam is opened gradually or in a sudden, careless manner, because hammering, which alone can cause an explosion, does not follow.

But it is to be observed that a rapid filling of the pipes with steam may prove disastrous, for the sudden heating up of the various parts may cause rupture due to unequal stresses on and resistance of the material.

When, however, a large quantity of water is contained in the pipes and the steam is forced to find its way through it and to carry it along, an explosion may occur, even if the stop valve is opened in the slowest and most careful manner.

If there is so little water in the pipe that steam need not force its way through it, no disastrous hammering will occur, nor will the water present be carried along by the steam when the stop valve is opened, as was demonstrated by the amount of water left in the pipe after the end of all tests.

The results of the tests with the first arrangement of the second experimental pipe lead to the conclusion that where water has accumulated in U bends of pipes, if the stop valve is opened gradually, the entering steam will distribute itself at once uniformly over the surface of the water, and by virtue of its pressure, which, in spite of the original condensation, is not only maintained but steadily increased, will prevent any agitation of the water, and, consequently, hammering. If, however, a sudden change of pressure and a rapid influx of steam occur, then the water will be agitated and, once in motion, it will cause violent and dangerous hammering in the pipe. Therefore, steam pipes with pockets are to be avoided.

The variation of the pressures indicated on the gauges after all the tests, leads to the conclusion that the water is thrown backwards and forwards, wave-motion like, caused by the influx of steam, and that the pressure is greater or less, depending on the intensity with which the moving mass of water strikes the opening to which the gauge is attached.

ERRATA IN THE PAPER ON "TEST OF WOUND COPPER PIPES" IN THE AUGUST NUMBER OF THE JOURNAL.

Page 518. Change the formula at the foot of Table I to

$$t = \frac{pD}{5{,}689} + 0.059.$$

Pages 518 and 519. Cross out the word "Pounds" in the last column headed "Factor of safety."

Page 521. Change the reference marks † and ‡ in the fourteenth column of Table IV to the seventeenth column, same lines.

LIQUID FUEL FOR NAVAL PURPOSES.

By Passed Assistant Engineer John R. Edwards, U. S. Navy.

[One of a series of lectures delivered at the Naval War College, Newport, R. I., August, 1895.]

INTRODUCTORY.

Intimately connected with the boiler question is the subject of fuel, for the efficiency of the steam generator depends to a considerable extent upon the combustible used. In the Pocahontas and Cumberland varieties of bituminous coal, and in several anthracites, we have fuels which are superior to that mined by any other nation except England. The better the coal, the more quickly it will deteriorate, for the hydro-carbons will volatilize unless exceeding care is taken. In the bunkers of a modern war vessel, the coal is subjected to a light roasting, for with the protective deck just over the boilers, and forming the flooring of the bunkers, the coal must be quickly impaired. A squadron investing any of our ports will therefore suffer from the impairment of her fuel, for even with banked fires under all furnaces the bunkers will be heated up to some extent. We shall therefore be on an equality with any nation which attemps to blockade our ports, so far as the efficiency of coal is concerned.

This is an experimental age, and no nation can be said to have solved the fuel question for war ships until it has satisfied itself concerning the worth of petroleum residuum as a combustible.

War vessels must have the best fuel within reach. It is not a question of finance. It is one of strategy and necessity. To gain a half knot speed for their war vessels, the Japanese bought Welsh coal of medium quality, and it cost them over six times as much as coal from their own mines would have done.

AMERICA'S KNOWLEDGE OF THIS SUBJECT.

Some of our officers labor under the great mistake of believing that our country has done nothing to find out the advantages and disadvantages of this combustible. The greatest corporation in the world, the Standard Oil Company, has a direct interest in this matter, and the money expended on the Continent in the investigation of this question, is but a fraction of that incurred indirectly by the Oil Trust. The Bureau of Steam Engineering has also made an exhaustive series of experiments with various qualities of unrefined petroleum and its residuum.

The steam furnished by all the boilers at the Columbian Exposition, also at the California Mid-Winter fair, was generated by liquid fuel. It may surprise our people to be told that we have had more success in America in burning this combustible than they have had anywhere else, except in Russia, and our Naval officers will be more than astonished to learn that a Naval Engineer on the retired list is without a peer in his knowledge of this subject.

NAVAL ENGINEERS DESIRE ITS SUCCESSFUL INSTALLATION.

Fleet Engineer Quick, of the Royal Navy, voices the sentiment of every Naval engineer when he tells of the wish and hope that the burning of liquid fuel may be a success. But he realizes that claims are not results, and so he says: "In these days of rapid development of machinery we are all of us tempted to wish that a vast leap forward could be made at once, so that we may have our power produced without the use of coal and steam on board ship. For more than thirty years the hope has been indulged that the use of liquid fuel would enable us to avoid the horrors of coaling ship; but even to-day we seem to be far off from this step forward being taken. Those who have had to superintend the coaling of a man-of-war in a tropical climate, when the steam has been up and the coal has been old and dusty, can alone realize what an immense blessing liquid fuel would be to all on board, if it could only be brought into constant use. But there are certain objections to its employment on board vessels of war, which objections do not apply to its use on merchant steamers or fast

mail boats, so that we must expect to see it employed successfully in the mercantile marine before it is used in vessels designed for fighting. It is true that those enterprising people, the Italians, are making strong efforts to introduce it into their war ships, but it is not impossible that an action at sea, in which high explosive shells may be used, may very much alter their views on this subject."

ADVANTAGES AS A FUEL.

Here are some of the advantages claimed for the burning of the residuum of petroleum:

1st. The saving of labor. As the oil is forced by pressure directly to the burners in the fire box of the furnace, all the handling of coal and ashes is done away with. In action it might be impossible to throw the ashes and cinders from the coal overboard.

The more perfect combustion of liquid fuel prevents the formation of residuals and smoke. Consequently, ashes and cinders do not occur, and the furnaces need not be cleaned, nor need the flues be swept. The first circumstance is of the greatest importance with regard to torpedo boats, which generally have only one furnace the grates of which, after a six hours' coal fire, at most after ten, are covered with clinker. It then becomes imperative to clean the grates if the steam pressure and speed are to be kept up.

2d. The saving in room. If this combustible were absolutely to be depended upon, the fire rooms could be made much smaller. But he would be a bold designer who would not make provision in an emergency for using coal. A saving will be effected, however, in some of the space now taken up by the bunkers.

The greater power of evaporation of liquid fuels, which is in the proportion of 7 to 4 to that of coals, enables steamers either to reduce the weight of the fuel they take on board, when the same distance is to be steamed as in the case of coal fuel, or else enables steamers to steam a longer distance when the same quantity of liquid fuel is taken as would have been required if coal had been used.

3d. The saving in men. The fire room force would be materially reduced if oil can be successfully consumed. On board torpedo boats one-half the fire room force now required could be dispensed with. As the men would have little physical work to do, they would keep better health in bad weather, whereas at present it is known that the firemen are the first to become exhausted.

4th. Preservation of the boilers. It is said that the fiercest action of the flame is upon the crown of the furnaces and not upon the ends of the tubes, and that where the boiler is strongest, the heat is the greatest.

5th. The rapidity and cheapness with which they can be brought on board. These, according to Tweddell, are so great that the steamers of the Caspian can ship from 800 to 1,000 tons of fuel in from three to four hours, a period which could be still more reduced if a few arrangements still wanting were introduced. A torpedo boat, therefore, which required at most about 21 tons of liquid fuel, could be made ready in a few minutes, and a whole flotilla would require no more time than it takes to coal a single boat at present.

6th. The storage of the oil in such parts of the vessel as are unfit for cargo. Such parts are the water ballast tanks of large cargo carrying steamers, the double bottoms of ironclads, as well as the keel spaces fore and aft of boilers and engines on all steamers. Besides, by filling up these spaces it will become possible to make the engine rooms more convenient and spacious, by reducing the bunkers, especially in the case of smaller vessels.

7th. The fires can be started more quickly and extinguished almost instantaneously. If well regulated, it is absolutely free from smoke. The control of the fires is an important matter, and particularly would this be the case on a torpedo boat. With such a fuel there would be no occasion to suddenly open the safety valve at an inopportune time. The abolition of smoke would be a practical as well as tactical advantage. The torpedo boat that does not betray itself by a column of smoke is very difficult to discover on the horizon, and will, therefore, have an enormous advantage, as it will itself be able to distinguish all larger vessels

by their smoke columns. As, however, a sudden stoppage of the air current will produce enormous dense smoke columns in cases where liquid fuels are used, it has even been suggested by a Naval captain that this circumstance should be utilized with a view of establishing a code of smoke signals, for long distances, on the Morse system.

8th. It can be adapted to any construction of boiler without material change in the existing arrangements for firing with coal, in fact, coal and oil can be used alternately if so desired. To burn oil alone, the fire bars have simply to be taken out or covered with thin slabs and cinders, the furnace doors have to be provided with holes for introducing the nozzle of the pulverizers, and the steam pipes and oil pipes have to be connected respectively with the boiler and oil tank. When oil is used, the stokers need not exert themselves much, whereas, where coals are used they have to work very hard, and must come on deck every few minutes to get a breath of air. For tropical climates, therefore, liquid fuel would have great advantages.

9th. The greater manœuvring capacity of the engines which is attained by the possibility of suddenly increasing, reducing, or stopping the fires. In case of coal fires, if it be desired to suddenly shut off the steam, and the safety valve is not to be used, the fire and smoke box doors have to be opened, and the cold air must be admitted directly into the boiler, which is exceedingly bad for the latter.

10th. The ease and exactitude with which the oil can be measured, when it is taken on board, as well as when it is being burned, should end all complaints of short weights in coals, which one hears so frequently now, and should also insure a better verification of the consumption of fuel during trial.

There are other advantages claimed:

(*a*) Increased radius of action.

(*b*) Better stability with fuel stowed in bottom of boat.

(*c*) Absence of necessity of having compartments open.

In general it may be said that one's imaginative power has become weakened when a new advantage cannot be found for the successful use of liquid fuel on naval vessels.

VALUE OF OIL AS COMPARED WITH COAL.

In the "Report of experiments in burning fuel oil" made by officials of the Baldwin Locomotive Works, it is stated that: "To determine the value of oil, it is necessary to know the evaporative power of the boiler for each pound of fuel burned, which depends greatly upon the ratio of heating surface to grate surface, and the volume consumed in a given time. These conditions do not seem to affect the consumption of oil, the evaporation being about the same per pound of oil for all rates of combustion, it being impossible to consume the oil without a proper supply of air, and, as no smoke is made, no unconsumed fuel goes out of the stack, as in the case with soft coal. The following formula will enable any one desiring to use oil to obtain a correct idea of its value, as compared with coal as fuel:

$$\frac{(\text{Cost of coal per ton} + \text{cost of handling (say 50 cents)} \times 10.7 \times 7}{2{,}000 \times \text{evaporative power of coal}} =$$

price per gallon at which oil will be the equivalent of coal. It must be remembered in these computations that the cost of both oil and coal is considered at the place where they are delivered to the engine, and not at the place where they are purchased by the railroad company."

COMMERCIAL APPICATION.

This lecture will only incidentally touch the commercial side of this question. The industrial applications of liquid fuel are vast in their possibilities. Some promoter may find some such wonderful use of it on shore, as Captain Curtis suggested at sea, when he proposed to signal with the clouds of smoke that would issue from the funnel when the fires would be suddenly checked.

Its commercial success on shore will depend to a great extent on its cost. And the cost will be determined everywhere by the proximity to the wells, and cheapness of transportation.

The "Shipping Gazette" of May 19th, 1894, says: "It has just been announced that the experiments which were carried on last year on the *Caledonia* will not be continued this season. Blast furnace oil—the only available liquid fuel—has risen so much in

price as to be more costly than coal for a given amount of steam generating work."

With reference to the use of liquid fuel on locomotives, it is interesting to refer to the results obtained in England by Mr. James Holden, Locomotive Superintendent of the Great Eastern Railway, by the process invented and adopted by him. On the locomotive using liquid fuel there is an absence of constant and laborious firing; the requisite pressure of steam is easily obtained by an almost imperceptible movement of the injector valve; there is an absence of smoke, and a great uniformity of pressure.

In the inaugural address of the President of the Society of Engineers, in February, 1894, he gave a description of these locomotives and their working cost. He stated that an express engine using 35.4 pounds of coal per mile, consumed under similar circumstances 11.8 pounds of coal and 10.5 pounds of liquid fuel, or a total of 22.3 pounds of fuel.

The advantages of the Holden system are summed up as follows:

1st. With an ordinary grate, steam can be easily raised without working the injector.

2d. Fuel can be interchanged according to the state of the market.

3d. With a thin coal fire, oil can be shut off at will without running the risk of chilling the fire box.

4th. When standing, the coal fire will maintain steam.

For several years a number of locomotive engines on the Great Eastern Railway have used liquid fuel, and one of these engines is recorded to have traveled 47,000 miles without a single failure or accident. But the great difficulty in extending the use of liquid fuel in England is the impossibility of obtaining a sufficient supply at a low cost, otherwise it would be very generally used, considering the great calorific effect and the practical advantages of its application.

It has been very recently stated that since the introduction in the naval ships of liquid fuel, the cost in Italy has increased one hundred and fifty per cent. (150 per cent.).

One of the highest officials of the Pennsylvania Railroad as-

serted that the great cost attending its use was a bar to its introduction in the locomotives of that road.

On the other hand, there are some places where it can be secured more cheaply than coal.

The question of cost, therefore, depends upon location.

A great writer upon this subject has said: "We must look for the best results from petroleum, both economically and technically, in those uses where the improved product of the manufactured article more than counterbalances the difference in price of the two kinds of fuel."

CHIEF ENGINEER SOLIANI'S MONOGRAPH ON LIQUID FUEL.

Undoubtedly one of the best articles that has been published on this subject is the paper of Chief Engineer Soliani of the Italian Navy, which was read at the International Engineering Congress. He starts in with the various kinds of petroleum used, gives the chemical composition, what its actual calorific value as fuel is, and then goes on to tell about the experiments in Russia, where it was first used on vessels in the Volga region and on the Caspian Sea. He then gives us the pulverizing process adopted by Mr. Urquhardt, and then brings us down to to-day's actual modern experience in the Italian Navy.

A careful study of this paper shows:

1st. That the only form of liquid fuel which is absolutely safe for use on board ship is what is known as petroleum refuse, which is a thick viscous fluid of about the consistency of tar or very thick molasses. This has to be sprayed or pulverized, either by jets of air or steam, for use in the furnaces.

2d. The pulverizers form the principal element in the whole arrangement for burning liquid fuel, and many kinds have been used or tried, or simply patented. The Russian pulverizers are all worked by steam, and they appear to be the best, because a pulverizer using steam may be worked well with air, or any other suitable gaseous fluid with little or no alteration.

3d. Where pulverizers are not used a compressor for forcing the air is employed. Its great weight and space occupied forms a very serious objection to the compressor.

4th. That the use of liquid fuel by the Russians is almost confined to the Volga region and the Caspian Sea. There the wood is scarce and costly, and also very bulky. Coal is extremely expensive. One very remarkable fact in connection with the use of liquid fuel on Russian vessels is that the difficulty with marine boilers of making up the waste of steam entailed by the pulverizers does not exist for the steamers running along the Volga River. It is lessened, in case of the sea steamers, by the fact that the great bulk of the Caspian trade is from Baku and other ports south to Astrakhan, where fresh water is available in abundance, and can be stored by the steamers both for outward and homeward passages.

5th. Italy, on account of its position and of its deficiency of coal, was naturally interested in the matter. And that country, which even our naval experts have, in years past, mistakenly reported as having adopted this fuel for its war vessels, confines the practice to a few torpedo boats. For their large vessels they do not contemplate the regular use of liquid fuel. Pulverizers, however, are fitted in order that they may be held in readiness for the same object as forced draft.

6th. The system of mixing petroleum spray with the coal seems to be on the increase in the French and Italian navies, and furnishes a ready means of rapidly increasing the steam pressure and speed, above that of the natural draft.

7th. That the measure of success in the burning of liquid fuel will depend upon the efficiency and durability of the pulverizer. Less than three years ago the Italians believed that they had solved this question for naval purposes by the invention of the Curriberti atomizer. They are now rather doubtful about this sprinkler satisfying all their wants. The French, who are following them more closely than any other nation, are about to use their own pulverizers.

QUANTITY OF RESIDUUM THAT CAN BE SUPPLIED.

Some of our officers believe that there is an unlimited supply of this liquid fuel. It must not be forgotten that the residuum is only one of the substances secured from the natural oil.

The treatment of natural petroleum in order to separate it into commercial products, consists in distilling the crude oil in retorts of suitable construction, and condensing the products passing over at different temperatures.

Thus, roughly speaking, the products may be divided into three groups:

First. The volatile oils passing over at temperatures up to 150 degrees centigrade.

Second The illuminating oils passing over from 150 to 300 degrees centigrade.

Third. The residiuum. In the Baku oil, the residuum is about one-tenth of the entire substance.

An exceedingly liberal estimate of the production of residuum which could be utilized for fuel places the amount within three and one-half million (3,500,000) tons. Assuming a ton of residuum to equal in calorific effect two tons of coal, we have a supply of liquid fuel equal to seven million (7,000,000) tons, a very insignificant quantity as compared with the consumption of coal in the world.

In order to compete as fuel, the production of petroleum will have to be greatly increased. This increased production will have to come from fields lying on the seacoast where it can be shipped in tank steamers and be carried at a reasonable cost. Unless there was a demand for the illuminating and lubricating oils from the petroleum, the residuum would have an excessive value.

There is no one who has made a more protracted and scientific investigation of its capabilities than Mr. Isherwood, and this is the result of his observations on liquid fuel as a combustible for naval purposes. In summarizing the work of the Experimental Board of which he was president, he writes:

"The experiments in question embrace those made with Col. Foote's apparatus at the Charlestown Navy Yard, and those made with other apparatus on different boilers in the New York Navy Yard, all of them, I believe, of considerable value, but never reported in full with the exception of one made about ten years ago, and which is now on the files of the Bureau of Steam Engineer-

ing. In every case the patentees abandoned the trials before they were completed, owing to the failure of their apparatus.

"The liquid oil has, in all cases, to be transformed into oil gas before it can be burned. This transformation can be made by the direct application externally of heat to the liquid, but the temperature of the oil on the vaporizing surface is higher than the temperature required to decompose it, the result being deposition of solid carbon in the form of coke which soon fills the vaporizing vessels and renders them useless. This coke is frequently so hard that cold chisels can scarcely detach it, and if thrown into a fire even in small fragments, it burns with excessive slowness, like graphite. Whenever the vaporizing vessel is subjected to a high temperature like that of a boiler furnace, the decomposition of the oil and deposition of coke go rapidly on, so that in the course of a few hours any vessel of practicable size is filled by it. All apparatus exposed to anything like furnace or flame temperature will inevitably fail from these causes in the future as they have in the past. To make trials with such devices will merely serve to confirm this fact. The smaller the vaporization vessel, and the higher the temperature to which it is exposed, the more quickly will it fail.

"A very large number of apparatus has been invented embodying substantially this principle or mode of direct vaporization of the oil, the only difference being unimportant variations of detail to render the inventions patentable, and in all cases the vaporizing vessel has been necessarily small in order that the pressure heat could be employed in the oil vaporization, and the highest possible temperature was used in order that a sufficient quantity of the oil might be vaporized in a given time. None of of the apparatus, when pushed to the maximum will last more than half a dozen hours.

"It is quite possible, however, to vaporize the oil by the indirect application of heat by means of steam or water intervention, so that the temperature of the vaporizing surfaces will be below the temperature of decomposition of the oil. This would be manufacturing oil gas in a costly manner, and the gas could afterwards be burned in jets in a furnace like illuminating gas,

but it would not be "burning petroleum," or any oil in the proper sense. The vaporizing apparatus to produce the requisite quantity of gas per hour for any considerable power would have to be enormously bulky, heavy and expensive; in fact, a complete gas making plant itself, and I do not believe after the gas is obtained that a sufficient quantity of it could be consumed per hour by any practicable arrangement of jets in a furnace to produce as much heat as could be obtained from coal burned at the maximum in the same furnace. Further, as the metal of the jets would be exposed to the high temperature produced by the combustion of the gas, the latter would be decomposed in them and they would quickly become stopped by the deposited coke. The heat from each jet would be directly radiated upon the metal of the surrounding jets and produce this effect. In fact, I have produced it in my experiments by exposing a small diameter iron tube through which common illuminating gas was passed to the heat of a row of alcohol lamps placed beneath it, when after a few hours the pipe became completely filled with coke; with oil gas this result would happen sooner. To make any such system an engineering success (which is very different from a commercial success) the metal of the jets and their connections must be thoroughly shielded from temperatures as high as that of the oil decomposition.

"The only method that has been attended with any success is that of 'atomizing' or spraying the oil by means of steam under sufficient pressure for the purpose, used in an injector placed outside the furnace, so as not to receive the high temperature of combustion. The oil in fine spray, excessively comminuted, is thus squirted into the furnace where it is decomposed at large and its constituents separately consumed. An ordinary Giffard injector is employed, and the smaller its nozzle the better it works. Even in this case, however, the injector will fill with coke after a considerable time, and requires to be unscrewed from its pipe and cleaned out, another being substituted meanwhile. In this manner oil fuel can be satisfactorily burned. All other methods have failed. Generally a bed of incandescent coal is required on the grate of sufficient extent to inflame the atomized

or sprayed in oil, but even this is not absolutely necessary though a great convenience, and its rate of combustion is excessively slow.

"Although the injectors are sufficiently durable, and the combustion of the oil satisfactory, the fatal objection to the system, and it seems an insuperable one, is that not enough oil can be burned in a furnace to produce the requisite supply of steam per hour from a boiler; nor can this difficulty be overcome by multiplying the injectors spraying into a furnace.

"The difficulty arises from the fact that the oil is not sprayed in pure atmospheric air, but into air greatly contaminated with steam and carbonic acid gas. In the combustion of coal on a grate pure atmospheric air enters beneath the coal, and its oxygen is nearly all absorbed in the lower strata of coal, the unconsumed air mixed with the gases of combustion rising through the upper strata. The rate of combustion of the coal is a maximum in the lower layers, the part resting immediately upon the grate, and diminishes very rapidly as the upper layers are approached, being comparatively small at the top layer, where, indeed, in many cases it is almost nothing. A piece of dry wood resting on the incandescent coal of a furnace will long remain unconsumed; it will distill and char, but not burn if air be prevented from entering above the bed of coal through the furnance door. Now, one-half of the gases above the coal is unconsumed air, but the effect of the other half of intermingled steam and carbonic acid gas with it is almost entirely to prevent combustion. Into such a mixture the sprayed oil is delivered. And although air may be admitted through the furnace door, and by induction with the injector, yet not enough can be made to pass in to supply more than a very slow rate of combustion, which cannot by any means known to me be increased. As a result an immense quantity of furnace would be required to burn a comparatively small weight of oil per hour. If more be thrown in than can be properly consumed, the remainder will pass off through the chimney accompanied by dense volumes of black smoke and stench of sulphur, due to decomposition of the oil by the furnace heat without air in proper condition for combustion.

"The pound of oil fuel will produce about two-thirds more available heat than the pound of good steam coal, both being burned in the same boiler in quantities per hour inversely as their economic efficiencies, but the slow combustion of the oil in comparison with that of the coal, both being consumed at their maximum rates, places it out of competition for the production of steam power, and particularly on board of steamers.

"I regard the use of oil fuel in any vessel whose machinery is required to develop its maximum power and produce high speed as hopeless."

A TALENTED AUTHOR'S VIEWS OF ITS POSSIBILITIES.

Marvin, in his "Region of Eternal Fire," writes so graphically of the possibilities of liquid fuel that the average reader is dazed by the brilliancy of his predictions. He believes that from Malta to Singapore the dusty piles of Cardiff coal are to vanish, for Baku will supply an inexhaustible amount of inexpensive petroleum refuse to take its place. From Singapore to Shanghai the cheaper grades of Australian, Chinese and Japanese fuels are to depart forever, for Rangoon will undertake the task of supplying a better and cheaper combustible to the district.

And his picture of the Russian firemen turning on the jet at Baku and then adjusting the flame, as the navigator takes his departure, is beautiful. From his view the man in this stokehold has no need to concern himself about anything until he reaches the mouth of the Volga, except the comfort of the passengers and his own mental improvement. His sole bit of trouble—that of burning a few handfuls of cotton waste or wood, to get up a little steam to start pulverizing the oil—is even abolished in some mythical arrangement of a furnace, where a small quantity of hydro-carbon gas is kept stored for this purpose.

This brilliant author is evidently better posted upon the industrial and political future of the trans-caucasian region than he is upon the value and future of their wells of petroleum fuel. From this prediction we turn to an English scientific authority for his opinion of the future.

A BRITISH EXPERT'S VIEW OF ITS CAPABILITIES.

The "Engineer," London, in one of its issues, says:

"We see, then, that the startling claims advanced by inventors of various systems of burning petroleum, have no real foundation in fact, and they tend to retard the use of oil fuel rather than promote it. The right spirit in which to approach the subject is, while not expecting too much in the way of evaporative efficiency, to bear in mind that it is unfair to compare its price with that of coal in England only, and to remember that it is a superbly convenient fuel, involving the least possible trouble in burning it. . . . . To utilize oil fuel, then, properly, it appears that marine boilers should be so constructed that they will, like Mr. Holden's locomotives, burn either fuel indiscriminately, so that as the cargo steamer moves from port to port she will always be able to provide herself with that form of fuel which can be had at the lowest price.

"Hundreds of patents have been secured for different methods of spraying and burning liquid fuel. The great secret of success seems to lie, in so arranging matters that the flame will not put itself out and prevent the oil from being properly consumed.

"As regards the spraying, that is usually effected by the use of steam; but the practice is very objectionable, because the quantity used is very considerable, and represents great waste of fresh water, which must be made up again for the sake of the boilers, at least in the case of sea-going steamers. The use of compresed air seems to be better, but it may be worth while to consider whether either air or steam are needed."

INSTALLATION OF THE SYSTEM AT THE CHICAGO EXPOSITION.

At the World's Fair at Chicago the boilers which furnished the steam for driving the machinery were all fed with crude oil. The conditions there were, of course, quite different from what would prevail aboard ship, but they were all in favor of a more successful burning of the liquid fuel. Lake Michigan with its supply of fresh water was near. There was no question of either weights or space occupied to be taken into consideration. The seven representative boiler firms which were pitted against each

other sent excellent men to look out for their respective plants. The piping was arranged in the most efficient manner, it not being necessary to make extra bends or angles in order that it would clear a hatch or opening, as might occur on board ship. And yet an official report says, "The quantity of petroleum used for firing the main boiler plant at the World's Columbian Exposition amounted to upwards of 31,000 tons, and the work done is stated to have totalled 32,316,000 horse power hours. This makes the consumption of oil about 2.1 pounds per horse power hour." This report would tend to dispose of some of the claims of the thermal efficiency of liquid fuel. Is it possible that the commercial article is not so rich in hydrogen as that furnished for experimental purposes?

A SUCCESSFUL OCEAN VOYAGE MADE WITH THIS FUEL.

The steamer *Baku Standard*, an ocean tramp, in 1894 made a voyage from Shields to Philadelphia, burning only liquid fuel. It is said that this is the first instance on record of a steamship fitted to burn liquid fuel and making an ocean voyage. The passage to Philadelphia was made under difficulties. Instead of the usual crew of firemen and trimmers, only three water tenders were shipped. One met with an accident soon after the ship sailed, breaking a collar bone, and was laid up. The result was that the other two water tenders had to stand six hours watch and watch alternately on the rest of the voyage, which they could scarcely have managed if they had to work hard shoveling coal and cleaning fires. As a fact, however, the fires seemed to have needed little or no attention, even in the worst weather. On this trip the weight of the steam used in the pulverizers to spray the oil, exceeded the weight of the oil, and at least 10 per cent. of the steam was wasted in this way. If there had not been an evaporator aboard, the result to the boilers might have been serious, in pumping so much salt water to make up the deficiency.

It is said that the *Baku Standard* returned to Shields burning liquid fuel. So far as I can ascertain, she has not made any more long ocean voyages with liquid fuel, and the promoters of the scheme were evidently not overjoyed by the result. It proved,

however, that ocean voyages could be made by vessels burning such a combustible.

Of the many articles written about liquid fuel, little else is told but the many advantages that will accrue from its successful use.

ITS DEVELOPMENT IN EUROPE FOR NAVAL PURPOSES.

We hear of the amazing progress that the Italians have made in their development of the burning of liquid fuel, and yet, only about two years ago, one of their highest officers practically said that if the use of petroleum in the torpedo boats of the Permanent Squadron proves to be a success, all their boats would be fitted with it.

It is exceedingly difficult to secure positive information in regard to the success of the Italians, but the following statement expresses nearly the extent of its installation on torpedo boats. Four have been fitted and four more altered.

From time to time we hear of the success attained by one of their cruisers on a short run with this fuel. A careful investigation invariably shows, that when oil was used in connection with coal, the speed over that of natural draft was increased. There is not one single instance on record where the burning of liquid fuel, either alone or in combination with coal, developed the speed or horse power that was secured with coal under forced draft.

For the past year, the Austrians have been experimenting with it. It is said that for every pound of residuum they were able to burn, seven-tenths of a pound of water in the form of steam was required to spray it. They have not yet been convinced of its merits for naval purposes, for not a single boat in the Austrian service has yet been fitted permanently with atomizers for burning this fuel.

A careful reading of the professional papers in regard to the success of the French with this combustible furnishes one with such information as the following: "The question is altogether in a state of tentative experiment, and the fuel will have to be tried in different boilers and under severe conditions before adoption in large vessels." Of another vessel it is written: "The

results are said to be good, but not definite." Concerning three torpedo boats it is written: "The experiments have been more or less successful."

The latest experiments made by the French authorities were with the *Forbin* and *Milan*. "On board the *Forbin* the results proved fairly satisfactory, but on board the *Milan* they did not have such good results." This is, of course, very indefinite, but it is the best information obtainable.

COST NOT A FACTOR FOR NAVAL PURPOSES.

The question of cost should not be taken into consideration in determining its value for naval purposes. I am convinced that it will cost more than coal as a fuel to do the same work. The cost of details, whose successful operation may cause great results, cannot be inquired into. If it can be successfully burned in large quantities for any long period, then its installation on naval vessels will be secured, no matter how expensive it may be. And it is for this reason that the oil producers have incurred so much expense in trying to make it a success.

I believe that it should be fitted immediately to at least one of our small vessels. We can well afford to experiment with this fuel, but it must be well understood that the outlay may be very heavy before success can be assured.

The Engineer-in-Chief has recommended in several of his Annual Reports that Congress should make an appropriation to enable him to make experiments with this fuel. It might be possible for this College in some way to ask that this purpose be carried out.

In 1888, a Board of U. S. Naval Engineers reported, "We are of the opinion that the system could be advantageously put on board torpedo boats and coast defence vessels, if safety in stowage and handling can be clearly arranged, and think the device worthy of a trial, particularly as it can be applied without interfering with the coal burning arrangements." This is even farther than Italy has gone in this matter, for she has only four torpedo boats actually fitted for burning such fuel.

DISADVANTAGES AS A FUEL.

The disadvantages are:

1st. The erection of oil tanks and supply pipes in the place of existing coal stations, so as to insure the rapidity of taking oil on board alluded to above.

2d. The loud noise occasioned by sprinklers, which is exceedingly inconvenient in the case of passenger steamers. It would be downright fatal for torpedo boats.

3d. The combustibility of oil, which might occasion an explosion in the event of a shell hitting the tanks.

4th. The very small number of oils which can be used as a fuel. If estimated at a maximum, the annual output of all the natural oil of the world amounts to about six millions of tons of mineral oil, three quarters of a million tons of tar oil, and a quarter of a million tons of slate or shale oil, altogether seven million tons. Modern industry, which transforms these into liquid fuel, lubricating oils, benzole, paraffin, etc., cannot spare them; at most it can leave us about 20 per cent. of the original weight in residuals, which, however, would only represent a fifth part of the fuel required annually by the steam navigation of the world. On the other hand, the latter absorbs about a thirty-third of the annual output of four hundred millions of tons of coal of the world, or twelve million tons.

5th. The enormous cost of liquid fuel at present is, however, the rock on which all attempts at introducing its use more widely in merchant vessels must founder. According to the present prices of coal and oil residuals, the latter, notwithstanding their higher power of evaporation, are about three times as dear as coal. The price of the oil will always be unstable.

6th. Difficulty in overcoming the objectionable odor. This objection was one of the reasons why the Southern Pacific Railway abandoned the use of petroleum fuel in the furnaces of their ferry boats.

The impossibility of overcoming the formation of gas and the consequent odor, and also the difficulty of examination of compartments in which this material has been carried, will retard

somewhat its adoption on board ship, even if the other difficulties were removed.

7th. Destructive action upon the plates and rivets. One of the officials of the Standard Oil Company, in discussing the paper of Colonel Soliani, says: "We have four ships running out of New York carrying petroleum to foreign countries, and about every two years it is necessary to cut out and renew a large number of rivets in the plate edges, sometimes reaching up into the thousands, in order to overcome the deteriorating effect incident to the penetration of oils along the laps of the seams. It will affect water bottoms in the same way, and to fully as great an extent. There is a great difference between the carrying of refined oil or the raw product. In the latter, the generation of gas is the maximum, in the refined it is the minimum. A few years since, the Standard Oil Company, of New York, built a steam vessel for the carrying of refined oil, and she was reasonably successful and satisfactory. Later they attempted to carry crude petroleum in her, and within three months thereafter they had a very disastrous explosion on board, practically wrecking the vessel."

8th. Exceeding and intelligent care required to burn the fuel properly. Mr. P. A. Lennertz, who had charge of the building of eleven tank steamers for Nobel Brothers, in Russia, says: "I have seen boilers on board ships on the Caspian Sea, which have been left with open air holes in the fire doors after the burners had been shut off, and the result was cracked tube sheets, leaky tubes, seam and stay bolts."

9th. To my mind, it is a great mistake for those countries which possess no oil fields to experiment with this fuel for naval purposes. A late review says that Germany has taken this stand, and hereafter, except for purely scientific research, she will not experiment further with the residuum of petroleum as a combustible for the vessels of her navy.

With our great oil fields abundantly able to supply a manifold quantity of liquid fuel for naval purposes, it ought to be our policy to supplement the work that has already been done by a series of exhaustive experiments with this residuum as a com-

bustible. The Engineer-in-Chief should be given a torpedo boat and a small gun boat to experiment with, and the investigation of the subject of liquid fuel should be carried on regardless of expense. The naval engineering expert, who would have supervisory charge of the work, would see that, despite the breadth and cost of the experiments, no money was wasted. Nor would he permit the work to be crippled by conducting the investigation after the plans of non-professionals who were incapable of finding out its merits.

Dissertations upon liquid fuel are a favorite theme of the novice, and some of the material is unintelligible to the naval engineer.

The solution of this engineering question, can only be delayed by having non-professionals interfere with a careful examination of its merits and defects. The engineer alone can realize the possibilities of this incomparable fuel, but he must have facts, and not hopes and promises, to justify him in adopting it as a combustible for naval purposes.

TRIALS OF THE LAKE STEAMSHIPS *ZENITH CITY* AND *VICTORY*.

BY PASSED ASSISTANT ENGINEER B. C. BRYAN, U. S. NAVY.

These vessels were built for carrying freight on the Great Lakes. Their hulls were built by the Chicago Ship Building Company, and the machinery by the Cleveland Ship Building Company. The *Victory* has Scotch boilers built by the latter company, and the *Zenith City*, water tube boilers of the Babcock and Wilcox Company's marine type. The *Victory* went into service early in August, 1895, and the *Zenith City* in September, 1895, and since that time both boats have been running practically continuously.

The principal dimensions of hulls and machinery of both boats are given in the following table :

	Zenith City and *Victory*.
Length, keel, feet	380
over all, feet	400
Beam, moulded, feet	48
Depth, moulded, feet	28
Registered tonnage, *Zenith City*, tons	3,429
Victory, tons	3,340
Displacement at 16 feet draught, tons	6,617.9
Block coefficient at 16 feet draught	.813
Midship coefficient at 16 feet draught	.981
Water line coefficient at 16 feet draught	.896
Center of gravity of water line from stern to whole length	.507
buoyancy from stern to whole length	.498
above base to height of water line	.529
Metacenter above base line, feet	20.17
Tons per inch at 16 feet water line	37.61
Engines : Triple expansion, vertical, jet condensing :	
Cylinders, H.P., *Zenith City*, inches	22
Victory, inches	23
I.P., inches	38
L.P., inches	63

	Zenith City and *Victory*.
Stroke, inches	40
Valves, H.P. piston, diameter, inches	10¾
length of port, inches	2¾
I.P. slide	
steam ports, 2, inches	1½x36
exhaust port, 1, inches	4¾x36
L.P. slide	
steam ports, 2, inches	2½x60
exhaust port, 1, inches	6¾x60
Piston rods, diameter, *Zenith City*, inches	5⅛
Victory, inches	5
Air pump, single acting, lifting, diameter, inches	31
stroke, inches	15¾

Boilers:	*Zenith City*.	*Victory*.
Type	Babcock & Wilcox.	Scotch.
Number	2	2
Diameter, feet and inches	.....	14–8
Length, feet and inches	8–7¾	13–6
Breadth, feet and inches	12–2	.....
Height, feet and inches	14–8	.....
Number of furnaces in each	1	3
Grate surface, total, square feet	134	144
Heating surface, total, square feet	6,800	5,715
H.S. to G.S.	50.7 to 1	39.6 to 1
Diameter of tubes, inches	4 and 2	3½
Weight with water, etc., in steaming condition, pounds	173,876	335,787
Weight per square foot of heating surface, pounds	25.57	58.7

Their hulls are precisely alike except that the water bottom of the *Victory* is 6 inches deeper than that of the *Zenith City*. They were built solely and entirely for the purpose of carrying freight, and everything in the design has been subordinated to that end. They have but one deck, the interior of the hull being strengthened by stringers and longitudinals and partial bulkheads. The framing is entirely of channel bars.

For ease in stowing and discharging cargo, the engines and boilers are placed at the extreme after end of the vessels. At the extreme forward end are the quarters for the crew, leaving all the rest of the hold free and unobstructed. There are 11 hatches, 8 by 33½ feet, for the purpose of receiving and discharging cargo.

All the plates of the hulls are lapped and treble riveted along the ends and double riveted along the sides. Filling pieces or liners, triangular in section, are used where three sheets meet instead of drawing out the sheets themselves. The laps in all cases point aft.

The machinery of the two vessels is almost the same; in fact, the engines were built from the same patterns, the only difference being that in the *Zenith City* the high pressure cylinder was cored for a diameter of 22 inches instead of 23 to compensate for the higher steam pressure. The cylinders are not steam jacketed. The *Zenith City* also has an independent feed pump while that of the *Victory* is attached to the air pump beam.

In the construction of the machinery of these vessels economy was carried to the utmost, and there is no hand or machine work in any place where it can be avoided. The crank webs are steel castings bored out and shrunk on the pins and shafts. The main bearings have no brasses, being cored out for the reception of white metal, which is first run in and afterwards bored out. The crank pin ends of the connecting rods contain steel shells for the reception of white metal, and no brass is used in any portion of the engine where it can be avoided. The thrust bearing is an ordinary horse shoe thrust, 6 collars on the shaft working against 5 horse shoes. All the jaws on small connections are castings which are board out and tapped on the ends of the rods.

Trials of the machinery of these vessels were conducted by Chief Engineer J. H. Perry and Passed Assistant Engineer B. C. Bryan, U. S. Navy, in October last. The vessels were running on their regular trips at the time, only remaining in port a few hours to load or discharge cargo. The testing apparatus used was such as could be applied without delaying the vessels. The results of these trials are tabulated in tables A, B, C, D and E.

Each vessel was supplied with a 3-inch Worthington water meter fitted in the feed pipe between the pump and boiler, and the piping so arranged that the feed water could be passed through or around the meter at will. On the *Zenith City*, the meter was in constant use and frequent readings showed it to be running regularly and uniformly.

The exact number of pounds of water corresponding to one division on the index of a meter can only be determined by weighing the amount actually passed through in a given time, under pressure and at the rate at which the meter was run during the trial; and such a test can only be made when there are adequate means for weighing or measuring all the water passed for a period of several hours. It was intended that after the trial the meter from each vessel should be returned to the maker and subjected to such a test; but as the meter on the *Victory* was disabled on a previous trip the meter from the *Zenith City* was transferred and fitted in its place. For one day it ran satisfactorily but on the second day, just before the trial began, the casing burst, and the meter was rendered useless. This disabling of both meters rendered it impossible to measure the water evaporated in the boilers of the *Victory*.

The meter from the *Zenith City* will be repaired and tested, if possible, and a rate established, though it is evident from the results given in Tables A and B that its error is not very great.

Tests for entrained water in the steam were made with a Heisler throttling calorimeter, taking steam from the main steam pipe at the forward engine room bulkhead in each vessel, and at a distance of from 14 to 18 feet from the boilers; the steam being taken through a pipe tapped into the main steam pipe with perforations about 1 inch from the circumference of same. These tests were not entirely satisfactory, owing to defects in the arrangement of apparatus, but observation of the jets of steam issuing from the calorimeter showed that the steam from the boilers of the *Zenith City* was at all times drier than that from the boilers of the *Victory*. The tabulated results showed that the amount of moisture in the steam averaged about $\frac{3}{10}$ of 1 per cent. for the boilers of the *Zenith City* and about $2\frac{3}{4}$ per cent. for the boilers of the *Victory*.

It will be noticed from Tables C and E that the engine of the *Zenith City* made three revolutions more per minute, under practically the same conditions of wind and sea, than the *Victory*, while developing 284 I.H.P. less. As the propellers of the two vessels are of the same diameter and surface this can only be ex-

plained by supposing the blades of the *Zenith City's* propeller to have been set at a less pitch. This view is strengthened by noting the slip of the two wheels.

All the coal consumed on the various runs with both vessels was carefully weighed on platform scales and the ashes therefrom were weighed dry on the same scales.

Each of the two boilers of the *Victory* contains three furnaces, formed of Adamson rings, four feet in diameter and of sufficient length for Ætna grates of six feet. The furnaces debouch into a single combustion chamber 34 inches deep. The water space back of the combustion chamber is but 5 inches in width at the lower part; the connection sheet is stayed to the head by screw stays, riveted over, spaced $5\frac{1}{2}$ inches horizontally and vertically. The tubes are $3\frac{1}{2}$ inches diameter and are spaced $4\frac{1}{2}$ inches center to center. Between the center and each side furnace one row of tubes is spaced 6 inches horizontally to improve the circulation of the water. The tubes are carried higher and further toward the side of the boiler than is usual in marine practice. Yet, when nearly 29 pounds of coal were burned per square foot of grate per hour, there was no serious priming, though the steam contained considerable moisture, as was shown by the dripping from all the valve stem stuffing boxes. The draft was remarkably good, considering the height of smoke pipe (about 50 feet above grate), being at times as high as $\frac{4}{10}$ inch of water, and the Ætna grates gave no trouble and were well spoken of by the engineer force of the vessel. The boilers are set entirely above the fire room floor making it difficult to fire the four side furnaces with the grate bars at such a height.

They are designed for a working pressure of 175 pounds per square inch by gauge. The performance of the boilers was remarkably good, as appears from Tables D and E.

The boilers of the *Victory* weigh, with water, in steaming condition but without smoke pipe, 335,787 pounds. This corresponds to a weight of 175.8 pounds per I.H.P. (at the I.H.P. in Table E), and 58.7 pounds per square foot of heating surface.

The two boilers of the *Zenith City* are of the Babcock and Wilcox Marine type. Each contains ninety 4-inch and three hun-

dred and ninety-six 2-inch water tubes, each 8 feet in exposed length between headers; twenty 4-inch tubes, 4 feet 7½ inches long, for carrying the steam to the drum, and one hundred and thirty-two tubes, each 2 inches diameter and 4 feet in length forming the feed water heater in uptake. The sides of the boilers are formed of square tubes for the height of the furnace and round tubes above, all expanded into headers. Outside of these tubes the boilers were clothed with magnesia, and so perfect was the insulation that the boiler casing never became warm enough to burn the hand.

All the headers are made of lap welded tubing flattened and with ends closed by pieces welded in. All connection of headers with each other is by means of short expanded nipples.

Each Babcock and Wilcox boiler occupies a floor space of 12 feet 2 inches front, 8 feet 7¾ inches deep and 14 feet 8 inches to top of heater. The front and back incline 2 feet 6 inches from the base owing to the inclination of the headers and tubes. The uptakes receding from the center of the fire room makes the latter remarkably cool and well ventilated as well as roomy.

The total weight of the two Babcock and Wilcox boilers, including water and all fittings, ready for steaming, is 173,876 pounds, or 106 pounds per I.H.P. (at the I.H.P. given in Table C), and 25.57 pounds per square foot of heating surface; the boilers are, however, capable of developing considerably more power.

There is a Westinghouse air compressor fitted in the engine room, which discharges into a supply tank bolted to the fire room bulkhead. From this tank, pipes run to the corners of each boiler and terminate in jets inside. To clean the tubes it is only necessary to open the valve in the air supply pipe, when the soot will be blown off the tubes and carried up the smoke pipe without dust or dirt in the fire room or interfering with the firemen tending their fires.

The grate surface in each Babcock and Wilcox boiler was originally 72 square feet but this was reduced by a 9-inch wall of fire brick, dividing the furnace in two parts, to 67 square feet. The heating surface is 2,800 square feet in the boiler proper

and 600 square feet in the feed heater, or 3,400 square feet in all. All the tubes are expanded into the headers and the openings opposite the 4-inch tubes are closed by inner and outer plates and bolts, the joints being metal and metal; the openings opposite the 2-inch tubes are closed by screw plugs.

In service these boilers gave no trouble whatever. They carried their water steadily, and with only ordinarily good firing they will furnish all the steam at 200 pounds pressure that the engine can use. During the trial the safety valves lifted so frequently as to make the steam wasted a very appreciable quantity, and this loss is due entirely to irregular firing.

On both vessels the oiler was also the water tender, and it was not observed that the Babcock and Wilcox boilers required much more or closer attention than did the Scotch boilers to preserve a constant water level.

The coal used on each vessel was a good quality of free burning Pittsburg, or Western Pennsylvania, semi-bituminous, which gave off large quantities of very dark brown smoke and formed a moderate amount of clinker in the furnaces. It contained a large amount of lump, and required little or no working in the furnace after firing.

The power developed by the *Victory's* engine in the run from Devil's Island to Two Harbors, and given in Table E, may be taken as the very greatest it can develop, for the throttle was wide open, all the links were in full throw, and the steam was carried at the highest pressure allowed. The boilers of the *Zenith City* can easily be made to supply sufficient steam for this power, though for the reasons previously given, the corresponding revolutions per minute of the engine will be much greater.

The number of expansions in the *Zenith City's* engine during the run given in Table C was 24; the number in the *Victory's* engine during the run given in Table E was 16.

The drop from the boiler pressure to the initial pressure in the high pressure cylinders, as shown by the indicator cards of both vessels, was excessive, being in each case about 20 pounds at the highest powers developed by the engines. The openings for steam pipes were seven inches diameter, which would give a

steam velocity per second, at 90 revolutions of the engines per minute, of about 100 feet for the *Zenith City* and about 110 feet for the *Victory*, which is not excessive. There may be some contraction in the passages through the throttle valve which may partly account for the drop.

It is probable, however, that this drop in the cards is largely caused by the location of the indicator openings. These openings on the high pressure cylinders are in the steam ports close to the valves, and their lead is such that the steam flows by them and away from the openings. With steam pipes as large in diameter and as short and with as straight leads as those on these vessels, a drop of more than five or six pounds between the boilers and cylinders would not be expected. This excessive drop shown by the indicators reduces the I.H.P. and consequently the performance shown by the engines.

The vacuum was remarkably poor for jet condensers, vertical lifting air pumps and cold injection water, in both vessels. This was slightly offset in the *Victory* by the higher temperature, about 20 degrees, of the discharge water, corresponding roughly to about 2 per cent. in evaporation. An increase in vacuum of 4 inches would increase the power of the engines about 100 I.H.P. at 90 revolutions, or decrease the expenditure of coal for the present power 2 tons a day.

The independent feed pump of the *Zenith City* was run continuously at a speed sufficient to deliver at least twice the water required for the boilers, the surplus being discharged through the relief valve; consequently the expenditure of steam for this purpose is much greater than in the *Victory*, where the feed pumps are worked from the main engine.

It is to be regretted that there were no means by which the coal used for auxiliary purposes, such as heating ship, running pumps, dynamos and steering engine could be determined even approximately, as the amount would appreciably affect the coal per I.H.P. given in the tables.

Each vessel is supplied with the following auxiliaries:

2 ballast pumps, duplex, inches	12 × 16 × 18
1 auxiliary pump, duplex, inches	8 × 4 × 10
1 steam steering gear, 2 cylinders, inches	7 × 7
2 dynamo engines, single cylinder, inches	6 × 6
1 capstan, forward, 2 cylinders, inches	9 × 8
1 capstan, aft, 2 cylinders, inches	6 × 8
1 blower, 40-inch fan	
In addition to the above the *Zenith City* has 1 feed pump, duplex, inches	10 × 5 × 12

In compliance with a very common custom on the Lakes, the boilers and coal bunkers of both vessels are supported on platforms raised 6½ feet on the *Victory*, and 8 feet on the *Zenith City*, above the inner bottom in order that the space underneath may be utilized for cargo. Raising the boilers is of advantage in giving a better ventilated fire room and a direct entrance from engine room to hold, but has disadvantages also.

All the main bearings and the thrust bearings on both ships are lubricated with solid lubricants forced in from the cups which were provided with a plug or piston for this purpose. The crank pins, crossheads and the smaller bearings were lubricated with mineral oil. A small dribble of water was run on the eccentrics and thrust bearings as a precaution, but there was no sign of heating in any bearing during the trip.

Tables A, B, C, D and E follow on next pages.

TABLE A.

ZENITH CITY.

9 A. M. October 20th to 9 A. M. October 25th.

Time, hours	24
Revolutions, total	126,010
per minute	87.5
I.H.P. of engine, average	1,540.19
per square foot grate	11.5
H.S. per I.H.P., square feet	41.4
Steam, engine, gauge, pounds	190.75
1st receiver, absolute, pounds	57.7
2d receiver, absolute, pounds	20.12
Links, from full throw, H.P., inches	3¾
I.P., inch	1
L.P., inch	⅝
Throttle	10
Vacuum, inches	22.6
Temperature, fire room, degrees	66.1
injection, degrees	43.2
discharge, degrees	116.5
feed at boiler, degrees	188.7
Coal, total, pounds	83,420
per hour, pounds	3,475.83
per square foot grate, pounds	25.94
I.H.P., pounds	2.256
Ashes, total, pounds	7,341
per cent. of fuel	8.8
Draft in smoke pipe, water, inches	.293
Meter, total water, cubic feet	9,519
water per hour, cubic feet	396.625
total (temperature 116.5 degrees), pounds	588,179.01
per hour (temperature 116.5 degrees), pounds	24,507.46
pound coal, pounds	7.05
I.H.P. per hour, pounds	15.91
Calorimeter, gauge, pounds	183.3
thermometer, upper, degrees	380.5
lower, degrees	289.08

Strong head wind and light sea from 9 A. M. till 7 P. M. 20th, then moderating. Vessel very easy and engines racing but slightly.

From 6 till 9 A. M. 21st, light variable wind and smooth sea.

Dynamo running from 4·15 P. M. till end of run. Steam on heaters. Donkey pump running 2 hours 38 minutes to discharge ashes.

A number of the compartments were filled at start and were pumped out after weather moderated.

The coal and water per I.H.P. are the quotients derived from dividing the coal and water per hour by the I.H.P. and are, therefore, too great by the amounts used for auxiliary purposes and which could not be determined.

TABLE B.

ZENITH CITY.

Whitefish Point to Manitou Island.

Time, hours and minutes	9·56
Distance, nautical miles	113.5
Speed, knots	11.43
Slip of propeller (pitch, 16 feet), per cent	15.78
Revolutions, total	51,215
per minute	85.93
I.H.P. of engine, average	1,607.25
per square foot grate	12
H.S. per I.H.P., square feet	4.23
Steam, engine, gauge, pounds	195.2
1st receiver, absolute, pounds	59.9
2d receiver, absolute, pounds	20.9
Links, from full throw, H.P., inches	3¾
I.P., inch	1
I.P., inch	⅝
Throttle	10
Vacuum, inches	22.85
Temperature, fire room, degrees	62
injection, degrees	44.2
discharge, degrees	117.8
feed at boiler, degrees	182.5
Coal, total, pounds	35,388
per hour, pounds	3,562.55
per square foot grate, pounds	26.586
knot, pounds	311.79
I.H.P., pounds	2 216
Refuse from coal, per cent	8 8
Draft in smoke pipe, water, inch	.288
Meter, water, total, cubic feet	4,014.5
per hour, cubic feet	404.144
total (temperature 117.8 degrees), pounds	247,975.67
per hour (temperature 117.8 degrees), pounds	24,963.99
pound coal, pounds	7.007
I.H.P., pounds	15.54
Calorimeter, gauge, pounds	188.9
thermometer, upper, degrees	381.6
lower, degrees	290.3

Strong wind ahead, light sea; vessel easy; engines racing very slightly; a number of compartments filled.

The coal and water per I.H.P. are the quotients derived from dividing the coal and water per hour by the I.H.P. and are, therefore, too great by the amounts used for auxiliary purposes and which could not be determined.

TABLE C.

ZENITH CITY.

Time, hours	3
Revolutions, total	16,470
per minute	91.5
I.H.P. of engine, average	1,626.45
per square foot grate	12.14
H.S. per I.H.P., square feet	4.18
Steam, engine, gauge, pounds	191.66
1st receiver, absolute, pounds	55.7
2d receiver, absolute, pounds	20.5
Links, from full throw, H.P., inches	3¾
I.P., inch	1
L.P., inch	⅝
Throttle	10
Vacuum	22.5
Temperature, fire room, degrees	70
injection, degrees	42
discharge, degrees	117.3
feed, degrees	195
Coal, total, pounds	10,670
per hour, pounds	3,556.7
per square foot grate, pounds	26.54
I.H.P., pounds	2.187
Ashes, per cent. of coal	8.8
Draft in smoke pipe, water, inch	.313
Meter, water, total, cubic feet	1,218
per hour, cubic feet	406
total, temperature (117.3 degrees), pounds	752,480.4
per hour, (temperature 117.3 degrees), pounds	250,826.8
per pound coal, pounds	7.052
per I.H.P., pounds	15.42
Calorimeter, gauge	.....
Thermometer, upper, degrees	382 3
lower, degrees	288.67

Light breeze, smooth sea. Distance could not be obtained as vessel was in open lake where no ranges could be taken.

No water in compartments. Steam on heaters.

The coal and water per I.H.P. are the quotients derived from dividing the coal and water per hour by the I.H.P. and are too great by the amounts used for auxiliary purposes and which could not be determined.

TABLE D.

VICTORY.

2·45 P. M. to midnight, October 27, 1895.

Time, hours and minutes	9·15
Revolutions, total	47,725
per minute	85.99
I.H.P. of engine, average	1,438.8
per square foot grate	9 99
H.S. per I.H.P., square feet	3 97
Steam, engine, gauge, pounds	168.3
1st receiver, absolute, pounds	60.5
2d receiver, absolute, pounds	21.75
Links, from full throw, H.P., inches	$2\frac{5}{16}$
I.P. and L.P	Full.
Throttle	10
Vacuum, inches	21.65
Temperature, fire room, degrees	75.9
injection, degrees	44.9
discharge and feed, degrees	137.7
Coal, total, pounds	29,967
per hour, pounds	3,242.92
per square foot grate, pounds	22.52
I.H.P., pounds	2.24
Ashes, total, pounds	2,234
per cent. of coal	7.45
Draft in smoke pipe, water, inch	.364
Meter	Broken.

Run concluded at 12 midnight on account of inclemency of weather which obliged vessel to seek harbor.

At start, moderate wind ahead and light sea; wind and sea increasing till 6 P. M., when wind was strong from ahead with rough sea, and so continued till end of run.

From 6·30 till 7·15 engines raced badly and were regulated by throttle; from 7·15 the racing was moderate till 11·30, when it again became necessary to regulate speed by the throttle.

At start H.P. link in $1\frac{5}{8}$ inch, others full. At 7·15 H.P. link run in to 3 inches from full throw.

At 7 began filling double bottom compartments with water to steady ship; capacity of double bottom 2,500 tons.

Safety valves lifted at intervals during run. Water in gauge glasses $10\frac{3}{4}$ S., $7\frac{1}{2}$ P., at start, 6 inches in both at end.

Steam on heaters during entire time of run. Donkey pump running 30 minutes to discharge ashes. Dynamo running from 3·40 P. M.

The coal per I.H.P. is too great by the amount used for auxiliary purposes and which could not be determined.

The meter casing burst just as the trial commenced.

TABLE E.

VICTORY.

Devil's Island Light to Two Harbors.

Time, hours and minutes	3·1
Distance, nautical miles	38
Speed, knots	12.59
Slip of propeller (pitch 16 feet) per cent	10
Revolutions, total	16,000
per minute	88.4
I.H.P. of engine, average	1,910.8
per square foot grate	13.26
H. S. per I.H.P., square feet	2.99
Steam, engine, gauge, pounds	170
1st receiver, absolute, pounds	72.2
2d receiver, absolute, pounds	25.2
Links	Full.
Throttle	10
Vacuum, inches	22
Temperature, fire room, degrees	79.3
injection, degrees	43
discharge and feed, degrees	138
Coal, total, pounds	12,574.5
per hour, pounds	4,168.3
per square foot grate, pounds	28.94
knot, pounds	330.9
I.H.P. per hour, pounds	2.18
Refuse from coal, per cent	7.45
Draft in smoke pipe, water, inch	·33
Meter	Broken.
Calorimeter, gauge	
thermometer, upper, degrees	372.3
lower, degrees	238.3

Fresh breeze on bow; smooth sea; compartments filled, also water in hold. Steam on heaters. Both compartment pumps running, taking water from hold.

The coal per I.H.P. is the quotient derived from dividing the coal per hour by the I.H.P. and is too great by the amount required for auxiliary purposes.

EXTRACT FROM ADDRESS OF THE PRESIDENT OF THE INSTITUTE OF MARINE ENGINEERS.

By Mr. A. J. Durston, C. B., Engineer-in-Chief, R. Navy.

. . . . 2. We are now possibly on the eve of important departures from present practice in marine engineering, and you are aware from the discussion of the subject in the House of Commons that several vessels in the Royal Navy have been, or are being, fitted with water tube boilers.

The general question of the use of higher steam pressures, which necessarily involve, in my opinion, the use of water tube boilers, will be of interest to all members, and if it be shown by experience that increased pressures can be obtained with water tube boilers with safety and efficiency, and that a considerable gain in economy results from the use of such high pressures, no doubt the mercantile marine will be forced by competition to their adoption, assuming, of course, that any practical difficulties are shown by experience to be overcome when proper appliances are fitted. One very important reason for the adoption of very high pressures exists in the Navy, however, to a much larger extent than in the mercantile marine, and follows from the fact that with naval machinery, although possessing the capability of exerting great power, the usual power exerted on service of the naval ship is but a small proportion of the full power. It is well known that such small powers cannot be developed in a large engine with economy, and one advantage of the provision of very high pressures for the maximum power lies in the reduced size of engine which results, and which will have a beneficial effect in making the engine more economical at those low cruising powers which the vessel exerts during most of her life.

Besides this special advantage which accrues in the Navy, there is, of course, the general advantage of lightness. There

are certain types of war vessels where the development of the highest possible power for short spurts is of paramount importance, and this highest possible power is required on the lowest possible weight of machinery. . . . .

3. I imagine the members do not desire to be troubled with any information involving great technical detail, but there are a few other remarks I will make of a general character on subjects which all members of the Institution are interested in. These refer to practice in the Navy and Navy experience, and may be of use to members of the mercantile marine in dealing with their own problems. First, regarding the important question of leaky tubes in boilers, and experiments on the approximate temperature at which this occurrence takes place.

Some experiments were made at Devenport Dockyard in order to throw light on this, and also to ascertain the temperatures which were actually produced under practical conditions.

The results of a preliminary series of experiments were given in a paper read before the Institute of Naval Architects in March, 1893, and some of the leading points contained in that paper are shortly as follows:

First, tubes remained tight in a tube plate up to a temperature of about 750 degrees Fahr., but leakage must be expected when this temperature is much exceeded.

Secondly, as regards the temperatures which were attained under different conditions of working, it was found that when boiling water under atmospheric pressure in a plain vessel the temperature on hot side of plate was only 280 degrees with clean fresh water, but rose to above 550 degrees when the vessel was coated internally with a layer of grease $\frac{1}{16}$ inch thick.

The effect with boiling water under pressure was obtained by experimenting with a small boiler. This boiler, consisting of a cylindrical shell with tubes and a brickwork furnace at one end, was worked with a steam pressure of 145 pounds, air pressure 3 inches, the rate of evaporation being about 12 pounds of water per square foot of heating surface per hour. Two trials each of about five hours' duration showed a temperature on fire side of tube plate of about 750 degrees; at a third trial a small percentage

of oil (.07 of feed) was introduced into the boiler, and the temperature rose to between 750 degrees and 1,060 degrees on the fire side; at the fourth trial a small additional percentage of oil (.05) was introduced, and this caused the tubes to leak; the temperature became about 1,060 degrees on the fire side, and between 680 degrees and 750 degrees at the center of the tube plates' thickness, representing the mean temperature.

The experiments were conclusive in showing the importance of keeping the water side of the heating surface free from greasy deposit, and the water free from grease, and only confirms what is now well established in practice. To attain this end as nearly as possible, feed water filters are now commonly adopted in Her Majesty's ships, and also every effort is made to reduce the quantity of oil used for lubricating internal parts of engines to a minimum. As a means of preventing an excessive tube plate temperature near the tube jointings, the cap ferrule was introduced, a fitting which was fully described in the paper above referred to; and it only remains to add that, up to the present, experience has shown that this fitting has been very beneficial in preventing leaky tubes, and that the ferrule deteriorates but slowly on service.

The Devonport experiments were continued after those described in the paper of March, 1893, with the object of obtaining fuller information on the distribution of temperature over the tube plates and tubes. The result of one of these trials may be given. The boiler was worked with the steam pressure at 145 pounds per square inch, and air pressure at 3 inches, and the resulting temperatures of the fire box tube plate were, on the water side, 400 degrees; middle of plate, 617 degrees; fire side of plate, 750 degrees to 1,060 degrees; the temperatures of the tubes themselves were, on the fire side, 680 degrees Fahr. at fire box end, 617 degrees middle of length, and below 480 degrees at smoke box end.

During the series of experiments which have been made at Devonport, several other points were investigated, and some conclusions indicated, among which the following may be worth noting:

Brass and copper tubes are more liable to leakage than those of iron or steel.

Tubes of Lowmoor iron are as liable to leak as steel tubes.

The loss of efficiency, arising from a thin coating of grease deposit, was a substantial amount, averaging 11 per cent.

4. An occurrence in one of the new torpedo boat destroyers may also be mentioned as confirming the view that when the temperature is raised beyond 750 degrees, *i. e.*, about the temperature of melting zinc, leakage of tubes will occur. The vessel in question is fitted with four boilers, arranged in two stokeholds, two boilers in each, one main feed pump and one auxiliary feed pump being provided for each pair of boilers.

During a full speed run, a defective tube burst in the forward boiler, but this fact was not immediately recognized by those in the stoke hold; the water disappeared from the gauge glass, and in the endeavors to maintain the usual water level in this damaged boiler, the water became so low in the other boiler that the tubes were seriously overheated. Some idea of the temperature reached can be obtained from the fact that the solder securing the ends of the wire on the main steam pipes, and a zinc slab in the steam collector of the boiler, were melted, so that the temperature of steam had been above 750 degrees Fahr.

When the accident was realized, the defective boiler was shut off, and water pumped into the overheated boiler; the tubes of this latter leaked considerably at the steam collector joints, and required subsequent rerolling throughout, but no other repair. This incident took place in a water tube boiler, where the generating tubes enter the top collecting chamber below the normal water line; but a still more recent case of shortness of water and consequent overheating has occurred in a boiler where the generating tubes all enter above the water line, and in this case also tube leakage resulted, so that in every case the same result may be expected to occur if the critical temperature is reached.

It is satisfactory to note that in the case of the tube bursting, the safety appliances, viz., automatic ash pit doors and automatic stop valves on the boiler where the tube burst, acted efficiently, and no injury of any kind occurred; indeed, those in the stoke-

hold first ascertained what had taken place from inquiries made by those on deck.

5. Experiments have also been made with a view of ascertaining the steam pressure required to actually burst sound boiler tubes of small diameter, and the results obtained are of interest.

A copper tube, 1 inch in external diameter and 15 B.W.G. (.070 inch) in thickness was taken from a boiler of a torpedo boat destroyer that had been steamed under forced draft at the full power to a large extent, partly filled with water, and the ends closed. It was placed on a smith's forge, inclined at an angle of about 20 degrees to the horizontal, and a pressure gauge fitted at upper end. On being heated the pressure rose to 200 pounds, and the blast was applied. The pressure rapidly increased to about 1,500 pounds, then rose to about 2,000 pounds, the tube bursting 6½ minutes after pressure was first shown on gauge. The bursting pressure was not definitely noted, as the limit of the pressure gauge was exceeded, but as far as could be judged, only to a slight extent. The tube had apparently burst at the bottom next the fire; but the whole portion that was subjected to heat was split open and practically flattened.

Taking the bursting pressure at 2,000 pounds, this would correspond to a stress of about 14,700 pounds, or 6.55 tons per square inch.

By calculation, the temperature of the steam would probably be about 640 degrees Fahrenheit.

A similar experiment was made with a new steel tube intended for a torpedo boat destroyer boiler. This tube was 1¼ inches in external diameter, and 12 L.S.G. (.104 inch) thick, and had been coiled cold into a spiral of about 6 inches in diameter. This tube, which was half filled with water, burst at a pressure of 4,788 pounds per square inch, *i.e.*, 42¾ cwt., in which gauge was graduated; in this case, the tube separating and only flattening out locally. This pressure corresponds to a stress of about 28,800 pounds, or 12.85 tons per square inch. The temperature of steam in this instance would probably be about 800 degrees Fahrenheit.

Although it was endeavored to approach the circumstances of

actual working, it must be borne in mind that in these experiments the tubes were partially filled with water and only slightly inclined to the horizontal, whereas in water tube boilers where such small tubes are used, the tubes are generally more nearly inclined to the vertical; and in all cases there is a stream of water, or water and steam, passing through the tubes when generating steam.

6. Coming now to another question, respecting which every member of this Institution will have some data obtained from his own experience,—I refer to the proportions of boilers for the powers to be developed,—there appears to be still a great deal of misapprehension in some quarters as to the proportions adopted in the Navy, and it may be desirable if I explain what this practice is.

For the ordinary tank boiler, the size of boiler fitted is such that one horse power is developed from each $2\frac{1}{2}$ square feet of total heating surface on an eight hours' trial, termed the natural draft trial. For a shorter trial of four hours' duration, called the forced draft trial, this power is increased by 20 to 25 per cent., so that for this short period the heating surface is at least 2 square feet per indicated horse power.

On actual service, the minimum which it is insisted must be developed by the engines and boilers continuously for as long as the coal will last in the vessel, is 60 per cent. of the natural draft power, so that at this minimum power it will be seen that the heating surface is about 4 square feet per indicated horse power. This continuous power is clearly that which corresponds to the sea-going powers of the mercantile marine.

Although the Admiralty lay down this minimum power, there is no limitation of the amount obtained up to the full natural draft power, and on trials made expressly to ascertain the amount of power which can be continuously maintained, the minimum of 60 per cent. is generally considerably exceeded.

The table exhibited shows the results of a series of 14 trials and by inspecting the column No. 7, showing the heating surface for power actually developed, it will be seen that the Royal Navy and mercantile marine practice on this question is much the same.

7. No doubt members will have seen much discussion respect-

Trial at maximum continuous power.									Type of boiler.
1.	2.	3.	4.	5.	6.	7.	8.	9.	
Ship.	Type.	Load on safety valve.	Duration of trial in hours.	Indicated horse power.	Heating surface.	Heating surface per indicated horse power.	Coal per indicated horse power per hour.	Full natural draft power.	
		Lb. p. sq. in.			*Sq. ft.*	*Sq. ft.*	*Lb.*		
Royal Sovereign	Vertical triple	155	72	8,180	20,034	2.44	1.84	9,000	Cylindrical, single ended.
Royal Arthur	Vertical triple	155	72	8,821	24,828	2.81	1.85	10,000	Cylindrical, single ended.
Sans Pareil	Vertical triple	135	50	7,051	19,980	2.83	2.23	7,500	Cylindrical, single ended.
Sirius	Vertical triple	155	64	4,555	15,918	3.19	2.03	7,000	Cylindrical, double and single ended.
Pallas	Vertical triple	155	73	3,620	11,109	3.06	...	4,500	Cylindrical, double ended.
Resolution	Vertical triple	155	48	8,085	21,178	2.61	2 1	9,000	Cylindrical, single ended.
Cossack	Horizontal compound	130	48	1,435	6,836	4.76	2.51	2,200	Cylindrical, straight away.
Mohawk	Horizontal compound	130	48	1,998	6,836	3.42	2.7	2,200	Cylindrical, straight away.
Fearless	Horizontal compound	120	48	1,888	6,439	3.41	2.46	2,100	Cylindrical, straight away.
Spartan	Vertical triple	155	72	6,777	15,918	2 34	1.96	7,000	Cylindrical, double and single ended.
Bonaventure	Vertical triple	155	72	7,083	15,600	2.2	1.76	7,000	Cylindrical, single ended.
Partridge	Horizontal triple	145	48	719	2,087	2.9	2.1	700	Cylindrical, ——.
Vulcan	Vertical triple	155	48	7,236	15,868	2.19	1.86	7,200	Cylindrical, double ended.
Buzzard	Horizontal triple	140	48	1,232	3,892	3.1	2.4	1,400	Cylindrical, straight away.

ing the merits and demerits of what is known as the induced draft system of increasing the rate of combustion in boilers.

Induced draft was first tried in the Navy afloat on H.M.S. *Vesuvius* in 1875; in her case, a 6-foot fan running 570 revolutions was used in connection with a boiler having 42 square feet of grate surface, producing about the same draft as an ordinary chimney; in this ship was also tried the effect of discharging the gases through a horizontal chimney with the outlet astern. Mr. Martin, who deserves credit for his persistent advocacy and has largely associated himself with this method of increasing the rate of combustion, made some further experiments with the system, and showed that a considerable draft could be obtained with it.

In 1889, it was decided by the Admiralty to make a comparative set of experiments with a boiler fitted with this system of draft, and subsequently with Navy forced draft, and a locomotive boiler at Portsmouth was selected for the purpose.

The results of these trials showed:

(*a*) That with fans used to produce the induced draft, there was no difficulty in obtaining high rates of combustion.

(*b*) That, as compared with forced draft, there was an appreciable gain in evaporative efficiency.

(*c*) Moreover, the open stokehold, if properly ventilated, has advantages in comparison with the closed stokehold.

It was, therefore, decided to proceed further with the system, and try it on board a ship, and for this purpose H.M.S. *Gossamer* was selected, one of her boiler rooms being fitted with induced draft, the other retaining the forced draft system.

An extensive series of trials was carried out in that ship, the net result of which was to show that while on other grounds there was little to choose between the two systems, the great convenience and comfort due to the conditions involved in working with an open stokehold, in lieu of a closed stokehold, were very valuable.

In view of these results further practical adaptations of the system have been made.

H.M.S. *Torch*, a gunboat, has been fitted on this plan, and still later H.M.S. *Magnificent*, a first-class battleship, and both these vessels have passed satisfactorily through their trials, and extended experience of the actual working of the arrangements at sea will soon now be obtained.

8. There is another subject, gentlemen, on which I may be permitted to offer a few remarks as illustrating the connection between the Royal and mercantile navies.

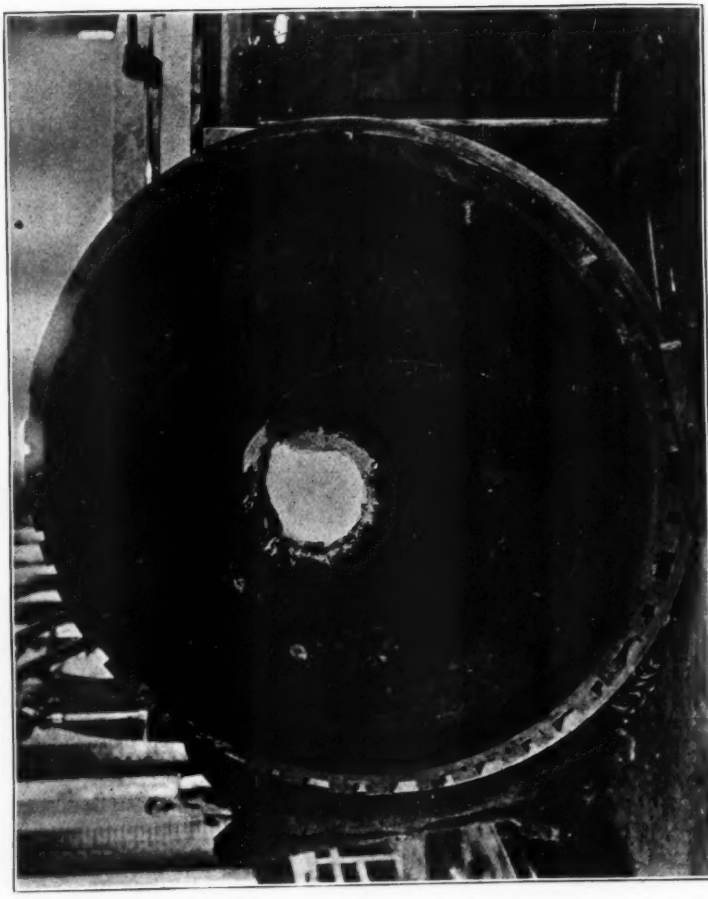
Many members of this Institute are Naval Reserve officers, and are, therefore, interested in the requirements of the Royal Navy.

We have at present about 200 engineers of the mercantile marine enrolled as Royal Naval Reserve engineers, and the opinion has been often expressed that a certain proportion of these gentlemen should be given an opportunity of joining the Royal Navy for a limited period of training, in order to become familiar with the discipline of the engine department of a ship-of-war, and to acquire a knowledge of what may be termed extra-professional duties, such as those in connection with locomotive torpedoes and hydraulic gun machinery.

It has hitherto been held that engineers in the mercantile marine are employed on much the same duties as those they perform if called upon to serve in the Royal Navy, and that consequently no additional training is required, but this is a question that necessarily requires careful consideration. Although a naval training is not required to the same extent in the case of a Reserve engineer officer, as in the case of the Reserve executive officer, yet to enable the Reserve engineer to undertake the duties and responsibilities involved in the charge of the engineer's department of a warship, some previous service in the Royal Navy would be of the greatest possible advantage. If a certain proportion of the Reserve engineer officers were given the opportunity of serving for a period in the engine room of a man-of-war, and were afterwards paid the same retainer as in the case of executive Reserve officers of corresponding rank, it would, in my opinion, tend to promote a feeling of patriotism and content on the part of the Royal Naval Reserve engineer, and as it would also afford an

opportunity of the naval engineer becoming acquainted with his brother of the mercantile marine, it would also promote a very desirable feeling of good-fellowship.

I cannot, in view of the official post I hold, discuss this matter very freely, but having observed that some prominence has been given to it of late, and notably so in a paper read before the Royal United Service Institution on May 10, 1895, by Commander Caborne, R. N. R., I have ventured to express my personal opinion on the desirability of affording engineer officers of the Royal Naval Reserve an opportunity of becoming acquainted with the routine work and discipline of a man-of-war in time of peace, in order that they may be prepared to at once accept onerous and responsible duties if called upon to serve in the Royal Navy in time of war or sudden emergency.



NOTES.

FAILURE OF A CAST STEEL PISTON ON THE U. S. S. *CHARLESTON*.

The following description and photographs of the above failure were communicated by P. A. Engineer S. H. Leonard, Jr., U. S. N., now on that vessel:

The U. S. S. *Charleston* has horizontal compound engines, with cylinders 44 and 85 inches in diameter by 36 inches stroke. Last May, while the cylinders and pistons were undergoing the usual examination, what at first appeared to be a scratch showed on the fillet of the hub of the L.P. piston of the starboard engine. Careful cleaning and scraping, however, showed well defined hair cracks completely encircling the hub.

An inspection of the inboard side of the piston showed ten sand or blow holes within a radius of six inches of the piston rod, all in the upper half of the piston. Nearly all these were surface defects, yet one showed a depth of 2 inches, while into another a wire was worked to a depth of fully 4 inches, a crack running directly through this hole. Other circumferential cracks also showed on the inner face and relatively in the same position as those on the outer surface, though somewhat less pronounced than the latter.

The cracks showed most distinctly on the outboard lower side. In taking clearances, the piston was found canted correspondingly, the bottom having moved about $\frac{5}{16}$ of an inch towards the inner head of the cylinder, and the top the same amount towards the other head. The follower, its bolts, the ring and its springs, were all found secure and in good condition. The piston rod nut was also solid against the face of the hub, and the rod accurately parallel with the crosshead slide. As there was no record or knowledge of any undue strain having been brought on the piston, the only reason that could be ascribed for its

condition was original and growing weakness, due to defective casting.

It was deemed that any further use of the piston would be dangerous, and it was accordingly removed. As a matter of interest to the Navy Department, as well as to the engineering profession at large, it was recommended that it be broken. This was accomplished at the Mitsu Bishi Works at Nagasaki, Japan, in the following manner:

The piston was supported at its rim, hub down, by four blocks placed 90 degrees apart; a steel collar 10 inches in diameter and 8 inches deep was placed directly on the center of the piston for the cast iron "dummy" to fall upon, the latter weighing 1,800 pounds and capable of being lifted 25 feet by the crane in the erecting shop. But four drops were necessary to knock the hub free from the disk, at the same time splitting the piston radially at two points—in one instance, clear through to the outer rim, and, in the second case, about three-fourths the distance. The results of the successive falls were as follows:

First. The cracks opened very perceptibly, especially on the under or hub side; several new circumferential cracks also developed.

Second. The cracks on the top side opened to fully $\frac{1}{8}$ inch and on the bottom to $\frac{1}{2}$ inch, scoria showing in the latter; the two radial cracks were also started and extended 12 inches in one case and 20 inches in the second.

Third. The cracks were still further opened, the shock throwing out fully a pint of scoria, fine coal, cinders and steel chips from the crack circumscribing the hub; the radial cracks extended about a foot towards the rim, one of the cracks assuming a spiral direction, while the other was straight. The sector enclosed by these cracks, at its inner end, was knocked fully 1 inch below the level of the surrounding disc, the fracture showing a fine close grain with no flaws.

Fourth. The boss or hub was knocked free, more scoria falling out. One of the radial cracks extended through the outer rim, the second extending to within 15 inches of the rim. The hub was found badly honeycombed, as is well shown in the

photographs, the section having approximately but 35 to 40 per cent. of sound metal; in fact, had an additional ¼-inch cut been turned off the boss it would have entered the honey combing in several places.

The nature and extent of the defect show the correctness of the cause ascribed, faulty casting, and also of the decision regarding its dangerous condition.

In this connection it may be of interest to refer to page 88, volume iv, of the JOURNAL, where it is stated that four out of five defective cast steel pistons for cruiser No. 11 were rejected on account of deep sand and blow holes *at the center*.

EVAPORATIVE TRIALS OF BELLEVILLE BOILERS.

The Belleville boilers constructed by Messrs. Maudslay, Sons and Field, at their works at East Greenwich, for the new twin-screw steamer *Kherson*, built by Messrs. R. and W. Hawthorn, Leslie and Co. for the Russian Volunteer Fleet, were officially tried on November 1, 1895. They were arranged in series at the works (the backs and sides being built up with fire brick) exactly as they will be on shipboard. The atmospheric conditions were not altogether favorable. The working of the boilers was studied by several engineers. The contract required that the evaporation on a trial of 12 hours' duration should be 8 pounds of water per pound of coal consumed. There are twenty-four boilers in all on the *Kherson*, placed in three separate water tight compartments. It was decided that it would be sufficient to test two of the boilers, their total grate surface being 93 square feet, and the heating surface 2,946 square feet. Each boiler consists of eight elements, each element containing 20 wrought iron tubes, 4½ inches in outside diameter and about 8 feet 6 inches long. As it would have been expensive to erect a chimney as high as that for the steamer, about 100 feet from the grate, a temporary uptake and short smoke pipe were erected, and the draft assisted by a steam blast. There was a preliminary trial of 6 hours' duration on Tuesday, October 29th, the results of which are given in the following table:

RESULT OF PRELIMINARY STEAM TRIAL OF TWO BELLEVILLE BOILERS AT EAST GREENWICH, OCTOBER 29, 1895.

Time.	Net weight of—		Evaporation per pound of coal.	Steam pressure. Boiler.	Pressure in blast pipe, in pounds per square inch.	Gas mixer.		Pounds of coal burned per square foot of grate.
	Welsh coal burned.	Water evaporated.				No. 17.	No. 19.	
	Pounds.	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*	*Pounds.*	
11 to 12 M.....	1,848	16,500	8.92	200	20	28	28	19.8
12 to 1 P. M...	1,747	16,500	9.44	200	23	28	30	18.7
1 to 2 P. M...	1,512	16,125	10.66	195	23	28	30	16.2
2 to 3 P. M...	1,747	16,500	9.44	195	23	28	30	18.7
3 to 4 P. M...	1,792	16,300	9.3	198	23	28	30	19.2
4 to 5 P. M...	1,568	17,000	10.84	198	23	28	30	16.8

The mean steam pressure was 197.6 pounds per square inch; mean evaporation per pound of coal, 9.76; average number of pounds of coal burned per square foot of grate, 18.23; mean blast pressure, 22.5; mean temperature of feed water, 64° F.

On the official trial also, Welsh steam coal of average quality was used. The fires were lighted at 5·40 A. M., the temperature of the atmosphere being 50 degrees Fahrenheit. By 6·20 A. M. the boiler pressure was 200 pounds, by the gauges, and ten minutes later a preliminary hour's trial was commenced, to allow the amount of coal and water used to be adjusted. From seven to eight, 18 cwt. of coal were burned, the evaporation being 8.8 pounds of water per pound of coal. The official trial commenced at 8 A. M., and continued for 12 hours, with the results given in the table on the following page.

During the first three hours the evaporation was equal to 9.2 pounds of water per pound of coal burned, and for the first six hours 9 pounds of water. At the end of the sixth and tenth hours the fires were cleaned, no allowance being made for this cleaning. The feed pump, of the special Belleville type, manufactured by Messrs. Maudslay, worked satisfactorily throughout, averaging about 11 double strokes per minute.

An accumulation test was next made to ascertain if the safety valves were capable of dealing with any quantity of steam likely to be produced. The valves were set at 245 pounds pressure, and the coal consumption was at the rate of 35 pounds to 40 pounds per square foot of grate surface per hour. This was con-

tinued for an hour, the maximum pressure recorded being 247 pounds.

EVAPORATIVE TRIAL, NOVEMBER 1, 1895.

Time. End of—	Coal burned.		Water evaporated.		Boiler pressure, pounds per square inch.
	Total, pounds.	Per square foot of grate, pounds.	Total, pounds.	Per pound of coal, pounds.	
1st hour.....	2,016	21.36	17,700	8.78	200
2d hour.....	4,032	21.36	36,000	8.93	200
3d hour.....	6,048	21.36	55,700	9.20	200
4th hour	8,064	21.36	73,500	9.10	200
5th hour	10,080	21.36	90,000	8.92	200
6th hour	12,096	21.36	108,000	8 92	200
7th hour	14,112	21.36	126,000	8.92	200
8th hour	16,352	21.66	142,800	8.73	200
9th hour	18,368	21 62	160,500	8.73	200
10th hour	20,272	21.48	178,700	8 86	200
11th hour	22,400	21.58	196,700	8.73	200
12th hour	24,104	21.39	212,300	8.80	200

Temperature of feed 54 degrees, constant throughout trial.

The mean results of the above give 8.88 pounds of water evaporated per pound of coal, and 21.43 pounds of coal burned per square foot of grate surface. The mean temperature of the feed water was 54 degrees Fahrenheit, and the mean boiler pressure, 200 pounds per square inch.

No calorimetric tests of the steam were made.

FRENCH NAVAL REGULATION FOR SIZES OF EVAPORATORS.

The ministerial circular of December 12, 1892, required that a tank should be fitted in each ship to hold fresh water for the boilers, and that the tank should have a capacity of about 525 gallons for each 1,000 horse power at maximum power.

Inquiry of the three squadrons on the 28th of March, 1895, showed the necessity of increasing the above allowance, preferably by increasing the power or capacity of the evaporators.

The following rules have therefore been adopted (Aug. 31, 1895,) for ships building and hereafter to be built:

1. The capacity of the fresh water tanks will remain as before.

2. The power of the evaporators will be 1,070 gallons a day for each 1,000 I.H.P. of the engines at maximum power.

3. The evaporators used will be on the triple system, with a capacity, in addition to that given above for make-up feed, of four times the daily consumption, on the basis of four litres per man. That is, it will be about 1,070 gallons a day for each 1,000 I.H.P. and 4 gallons a day additional for each man on board ship. On large ships this power will be in two plants, and on small ships, in one, but in the latter the distillers must be in duplicate.

A recent circular (October 8, 1895,) makes the following rules for the power of evaporators on torpedo boats, under construction or hereafter to be built:

In addition to supplying about 4 gallons of potable water per day for each man on board, the evaporators must be able to supply for seagoing torpedo boats, first-class, about 800 gallons; for second-class boats, about 935 gallons; and for third-class boats, from 1,200 to 1,335 gallons per day per 1,000 I.H.P. of the maximum power.

All torpedo boats will receive a reserve supply of about 270 gallons of fresh water for each 1,000 I.H.P. of the maximum power.

FACTORS OF SAFETY FOR MARINE BOILERS AND ENGINES.

The following review of Mr. Key's paper is taken from "Engineering," London, October 4.

Mr. John Key, of Hull, read a useful and suggestive paper on "Uniform Factors of Safety for Boilers and Machinery of Steamships." The author pointed out that no uniform code of international regulations has yet been adopted by maritime countries for the safety of ship machinery. The following Table will prove useful, as showing the working pressures allowed by various authorities with steel boilers as stated:

Steel shells.		Percentage of joint.	Admiralty.	Board of Trade.	Lloyd's.	British Corporation.	Hamburg.	Bureau Veritas.
Diameter. Feet.	*Thickness. Inches.*		*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
5 ×	⅝	70	133.8	116.06	86.3	102.08	109.4	113.3
5 ×	½	70	178.4	154.7	129.4	142.9	146.3	152.8
12 ×	⅝	80	127.47	117 7	111.1	114.6	111.2	112 4
12 ×	1	80	169.96	157 0	155 5	156.2	148.3	152.0
12 ×	1¼	80	212.45	196.2	200 0	197.9	185.4	191.6
16 ×	1½	82	196.0	181.04	187.9	184.2	170 9	177 7

The water pressure test allowed by the British Admiralty provides that not four-ninths of the ultimate strength of the shell shall be exceeded, and the working pressure is fixed at 90 pounds below the test pressure, which is called the "constant margin" of safety for all pressures. The Board of Trade allow a factor of safety 4.5, with additions according to the circumstances of each case. Lloyd's Committee add $\frac{1}{8}$ inch, and the British corporation add $\frac{1}{16}$ inch to all thicknesses for wear, and their constants vary according to the form of riveted joint. Hamburg rules allow a factor of safety 5.0, reduced to 4.7 when the longitudinal seams are drilled and double riveted. Bureau Veritas allows a factor of safety of 4.4 after the plates have been corroded away by 0.04 inch. These authorities all differ in their respective rules for diameter of shafts, thickness of plates forming flat surfaces, stress on stays, thickness of plain or corrugated furnace tubes, steam pipes and area of safety valves. The author quoted as an example of how unnecessarily we are hampered by want of uniformity even in boiler fittings and connections in the case of water gauges, that the English Board of Trade insist on having cocks or valves next the shell of the boiler, whereas the German Board of Trade will not have such a fitting. The consequence is that ships running to Hamburg are fitted with two standpipes, one with cocks and one without. To this the English Board of Trade has to shut its eyes, as the German standpipe, from their point of view, is unsafe, and ought not to be allowed.

There is no doubt, that the anomalies to which Mr. Key here draws attention have caused for some time past considerable inconvenience, and there is no good reason why they should not be removed. It waits for some one to take action, and Great Britain, as the leading maritime State, might appropriately take the initiative. It is to be hoped Mr. Key's paper will bear fruit.

THE TORPEDO BOAT DESTROYERS.

The following is abridged from an editorial in "Engineering," London, of November 8:

There has been a good deal of misconception as to the speeds of these boats, it appearing to be a frequent custom of the daily press to look on each trial chronicled as the "record performance." It will be remembered that in introducing the Navy Estimates last year (financial year 1894–'5), the First Lord stated that forty-two vessels of this class had been ordered by contract; it being a condition in these contracts that the vessels should be completed in the coming financial year. At the end of the year, however, it was found that the conditions as to time could not be fulfilled by certain of the contractors. Some had been affected by labor difficulties; and "in all cases," we were told, "the novelty of the design and the very high speed demanded have involved the expenditure of considerably greater time in construction and in trials than had been anticipated." As a matter of fact, some of the contractors discovered that they had undertaken a task of greater difficulty than they had anticipated, and, if it had not been for a very liberal share of help and advice from the Admiralty, they might have found themselves in a very unpleasant position.

The list on the following page gives the trial speeds of all the torpedo boat destroyers, with water tube boilers, of which we have records. The speeds given are those obtained on the three hours' official trials, with the contract weight of 30 tons in the shape of coal, spare gear, &c., on board.

TORPEDO BOAT DESTROYERS WITH WATER TUBE BOILERS.

Name.	Builders.	Length of vessel.	Description of boilers.	Speed on three hours' official trial.
		Feet.		*Knots.*
Bozer	Thornycroft	201.5	Thornycroft	29.17
Surly	J. & G. Thomson	200	Normand	28.05
Ardent	Thornycroft	201 5	Thornycroft	27.97
Bruiser	Thornycroft	201.5	Thornycroft	27.97
Starfish	Naval Construction Company.	190	Blechynden	27.97
Janus	Palmers	200	Reed	27.80
Decoy	Thornycroft	185	Thornycroft	27.76
Daring	Thornycroft	185	Thornycroft	27.70
Hornet	Yarrow	180	Yarrow	27.63
Salmon	Earle's	200	Yarrow	27.60
Shark	J. & G. Thomson	200	Normand	27.59
Banshee	Laird	210	Normand	27.57
Ferret	Laird	195	Normand	27.51
Rocket	J. & G. Thomson	200	Normand	27.37
Contest	Laird	210	Normand	27.36
Sturgeon	Naval Construction Company.	190	Blechynden	27.16
Dragon	Laird	210	Normand	27.14
Skate	Naval Construction Company.	190	Blechynden	27.10
Handy	Fairfield	194	Thornycroft	27.04
Lynx	Laird	210	Normand	27.00

An inspection of this table brings out the notable fact that some of these vessels have obtained a better speed on the full three hours than was made during the six runs on the mile. This is to be accounted for by the load becoming lighter owing to the coal being burnt. That seems a natural result, but it did not occur in old times, speeds nearly always falling off towards the end of a long trial. The type of boiler used affords an explanation. With the multi-tubular boiler, either of locomarine or return tube type, the fouling of the tubes, "bird's nesting" on the tube plates, and other causes—perhaps not the least the flagging of stokers under the excessive and long continued strain—caused a fall of steam pressure during the last hour or so. With water tube boilers of properly designed form, the work is much easier for the men, the space for combustion is larger, tubes do not get choked, there is no surface for "birds' nests" to form upon, and the proportions of the boiler allow of easier blowing. The con-

sequence is that an extended trial trip is no longer the trying ordeal it was formerly, and this is not the least of the advantages of the water tube boiler.

We believe the speeds given to be strictly accurate. In some instances our representative has been present, and in every instance we have obtained our information from a trustworthy source. In every case the guaranteed speed has been exceeded, in many cases very largely exceeded, in spite of the fact that there is no premium for extra speed. Vessels with the locomotive boiler are not included in our table, as such vessels are, it will be remembered, allowed a knot less than those having water tube boilers, that is to say, the contract three hours' speed is 27 knots for water tube boilers and 26 knots for craft with locomotive boilers.

The *Boxer*, which heads the list with a lead of over a knot, or a total superiority of 3½ nautical miles on the three hours' run, was up to a short time ago not only the fastest vessel in the British Navy, but also the fastest in the world. Within the last month, however, her speed has been exceeded by two vessels. The first, the *Sokol*, although constructed for a foreign power, has been built in England by Messrs. Yarrow & Co., made 29.76 knots on her three hours' trial. Her length is 190 feet. The other vessel, the *Forban*, was built by Messrs. Augustin Normand & Co., of Havre. Her length is 144 feet 4 inches. The load of armament, coal, crew, &c., was 16 tons. On an hour's run the mean speed was 31.029 knots.

There yet remain nineteen of the forty-two destroyers to complete their trials. Some of the above have locomotive boilers. If we add to the above the *Dasher*, *Charger* and *Havock*, the three boats by Yarrow & Co., with locomotive boilers, which have passed their trials, we have the total number of forty-two boats ordered.

The element of speed, although not the sole quality necessary for a successful destroyer, is one of the very foremost qualities, and, moreover, it is one upon which a definite conclusion can be arrived at. Speed is the final result of the combination which comprises the vessel—that is, her elements of design; and when

boats of one group are built to Admiralty requirements, and under Admiralty supervision, the fastest boat may be said to be the most successful. In estimating the speeds of these vessels, the state of the weather is a disturbing cause which cannot be allowed for. Contractors, however, are not likely to run trials when the sea is very rough. The measured mile courses are always near the coast, and though the wind may be high it does not necessarily mean that the waves are big when there is a weather shore. Again, some measured miles are more favorable than others for getting speed in large craft, or with small craft traveling at high speed. Until all boats are tried on the same course at the same time, we must trust somewhat to good luck.

It is often said that speed in these boats is a mere question of "brute force"—of cramming bigger engines into the boats. That hardly describes the situation. It is true the problem is largely one for the engineer; although Mr. Yarrow has shown us lately how speed can be much increased by an intelligent application of a knowledge of materials in hull construction; the French second-class torpedo boat, built of aluminium, and the *Sokol* being both instances in point. Still, the question is chiefly one of machinery. Now to put simply bigger engines and boilers into a given hull is not generally possible, but if the engineer can so design his machinery that he can get greater power out of the same space and weight afforded to less powerful machinery, there has been achieved a triumph of which he may be justly proud; and he is entitled to every credit for the additional speed of vessel. The working of the boilers is an important matter in this respect. One design may give a higher duty per square foot of heating surface than another. We have heard it objected that the speed in certain cases was only obtained by blowing harder; but some types of boiler will not stand blowing harder. It is a point worth considering by those who design these vessels.

The new torpedo boat destroyers, which are to follow the forty-two above dealt with, were originally intended to be twenty in number. Their guaranteed speed is 3 knots faster than that of the first lot, namely, 30 knots. We believe, however, that up to the present only twelve of these vessels have been ordered. They are not

all of the same dimensions, but some, at any rate, will not exceed in size the largest of the forty-two. The extra speed will, therefore, have to be obtained chiefly by an increase in power. No doubt advantage will be taken of recent experience to lighten the scantling of the hulls, but whatever the resources brought to bear, it will be anxious work to get the guaranteed speed.

The new boats are named as follows: Messrs. Thornycroft's vessels, *Desperate*, *Fame*, *Foam* and *Mallard*, 5,400 I.H.P., 272 tons displacement; Messrs. Laird's, *Quail*, *Sparrowhawk*, *Thrasher* and *Virago*, 6,000 I.H.P.; Messrs. J. and G. Thomson's, *Brazen*, *Electra*, *Recruit* and *Vulture*, 5,800 I.H.P. The last eight are to have a displacement of 300 tons and Normand water tube boilers.

The load, we understand, is to be 30 tons, as with the former craft, so that the larger vessels will have an advantage of a smaller proportionate deadweight.

SHIPS.

UNITED STATES.

Battleships Nos. 5 and *6*.—The battleships were partially described on page 581 of the last number. The following information has since then been received. The cost of each of these ships is not to exceed $4,000,000, exclusive of armament. One of them is to be named *Kearsarge*, according to the act of Congress authorizing the construction of these ships.

Length between perpendiculars, feet	355
on load water line, feet	368
over all, feet	371
Beam, moulded, feet	72
extreme, feet and inches	72–2½
Freeboard, forward, feet and inches	14–3
amidships, feet and inches	11–0
aft, feet and inches	12–3
Draught, mean, normal, with 410 tons coal, feet and inches	23–6
Displacement at this draught, tons	11,500
Speed, knots	16
Area of midship section, square feet	1,623
load water plane, square feet	19,833
Wetted surface, square feet	30,000
Tons per inch of immersion	47.30
Moment to alter trim 1 inch, foot tons	948.5
Draught, mean, 1,210 tons coal, all stores, &c., feet	25
Displacement at this draught, tons	12,350
Metacentric height (25 feet draught) feet	4.5
Range of stability at same (12,350 tons displacement) degrees	57½
Maximum righting arm, feet	2.08
moment, foot tons	25,688
arm, angle of, degrees	32

There will be five torpedo tubes.

The height of axis of forward 13-inch guns above the normal L.W.L. will be 20 feet 8 inches; of the after 13-inch guns, 19 feet; of the forward 8-inch guns, 29 feet 3 inches, and of the after 8-inch guns, 27 feet 8 inches.

All armor is to be of Harveyized nickel steel. The water line belt will be 15 inches thick at the top and 9½ inches at the bottom, amidships, and have a depth of 7 feet 6 inches, the top of this belt to be 3 feet 6 inches above normal L.W.L. This belt will be of the above thickness abreast of the engine and boiler spaces; forward of this it may taper gradually to 4 inches; it will extend at least from the stem to the after barbette.

Thickness of side armor above water line belt, 5 inches; of superstructure armor, 6 inches; of 13-inch turret armor, 17 and 15 inches; of 8-inch turret armor, 11 and 9 inches. The barbette armor will be 15 inches thick, and the conning tower, 10 inches. The protective deck will be from 2¾ to 5 inches thick.

The hull will be of steel, unsheathed. There will be two military masts with fighting tops.

The total coal bunker capacity will be not less than 1,210 tons, stowed without trimming by hand.

Bidders for these ships may, if they desire, adopt the plans for the machinery proposed by the Navy Department in whole or in part, but all designs of machinery must fulfill the general requirements of the specifications prepared by the Bureau of Steam Engineering.

The cylinders will be 33½, 51, and 78 inches in diameter with a piston stroke of 48 inches. The H.P. cylinder of each engine will be forward and the L.P. cylinder aft. Piston valves will be used, one on the H.P., two on the I.P., and four on the L.P. cylinder. The valve gear, Stephenson link motions, will be interchangeable. There will be two condensers with a total cooling surface of 14,000 square feet measured on the outside of the tubes.

The propellers will be right and left, of manganese bronze or approved equivalent metal. There will be an auxiliary condenser in each engine room, having not less than 800 square feet of cooling surface.

Each main air pump will be double, vertical, single acting, worked by two inverted steam cylinders. The main circulating pumps will be of the centrifugal type, worked independently, one for each condenser.

Each auxiliary condenser will have a combined air and circulating pump.

There will be five cylindrical steel boilers, three double-ended and two single-ended, in four compartments. The total grate surface will be about 685 square feet; and the total heating surface about 21,500 square feet, measured on the outside of the tubes.

Each of the double-ended boilers will have eight, and each single-ended boiler four corrugated furnace flues, 39 inches internal diameter.

The mean outside diameter of all boilers will be about 15 feet 6½ inches. The two forward double-ended boilers will be about 19 feet, the after double-ended boiler about 21 feet, and the single-ended boilers about 9 feet 11½ inches long.

There will be two main feed pumps, one in each engine room. Approved auxiliary feed pumps will be placed in the forward fire rooms of the after boilers, in the after fire room of the forward boilers, and in the fire room of the after single-ended boiler. In addition there will be approved auxiliary feed, bilge, water-service, fire and other pumps.

There will be two smoke pipes.

The forced draft system will consist of one blower for each fire room, the blowers discharging into air-tight fire rooms. Air-tight bulkheads will be fitted to reduce the space under pressure.

There will be steam reversing gear, ash hoists, turning engines, auxiliary pumps, engine for workshop machinery, hydraulic pumping plant for various purposes, gun table or turret turning engines, a distilling and evaporating apparatus, and other supplementary machinery.

The weight of the machinery is not to exceed 1,100 tons.

Other general requirements for these vessels are as follows:

1. The average speed to be maintained on trial for four consecutive hours, under conditions prescribed by the Secretary of the Navy, shall be not less than 16 knots.

2. If the average speed falls below 16 knots and exceeds 15 knots, the vessel will be accepted, but a reduction in the contract price will be made at the rate of $100,000 per knot.

3. Should the average speed fall below 15 knots the Secretary of the Navy may, in his discretion, reject or accept the vessel at a reduced price, to be mutually agreed upon. In case of rejection of the vessel the contractors must refund any money that may have been paid on account.

4. Three years from date of signing the contract are allowed for the construction of these vessels.

5. All designs of the vessel submitted by contractors, in case the Department's designs are not accepted as a whole, must be in sufficient detail and accompanied by such plans, specifications and calculations that the Department may readily determine the value of each design.

Brooklyn.—This armored cruiser, described on page 805 of Volume IV (see also Vol. V, page 201), was launched from the works of the William Cramp & Sons' Ship and Engine Building Company, Philadelphia, on the 3d of October.

Nashville.—Gunboat No. 7, described on pages 722–727 of Volume V, and page 176, Vol. VI, was launched by the Newport News Ship Building and Dry Dock Company on the 19th of October.

Wilmington.—Gunboat No. 8, described on pages 727–729 of Volume V, and page 176, Vol. VI, was launched on the same day as the *Nashville*, having been built on the same slip.

Katahdin.—This harbor defense ram, previously described on page 202 of Vol. V, had her official trial in Long Island Sound on October 31. The measured course was 34 nautical miles long—two runs of 17 miles being made. The average corrected speed was 16.1146 knots. A full description of the trial will be given in the next number of the JOURNAL.

Gunboats Nos. 10 to *15.*—Bids for the construction of these boats, of which a description was given on pages 581–583 of the last number of the JOURNAL, were opened at the Navy Department on October 1.

The proposals were for the construction of (1) four light draught composite gunboats, *Nos. 10–13*, of about 1,000 tons displacement each, having a single screw and full sail power; (2) two light draught composite gunboats, *Nos. 14* and *15*, of

about 1,000 tons displacement each, having twin screws and carrying steadying sails only.

Bids were asked for under the usual classes:

Class I.—Hull and machinery according to the Department's plans and specifications.

Class II.—Hull and machinery according to the bidder's plans and specifications.

The following bids were received:

Names of bidders.	Class of bid.	Type of vessel.	Number bid for.	Price bid.	Deduct for omission of—			Increase for the addition of steam windlass.
					Steam windlass.	Steam steerer.	Electric plant.	
Lewis Nixon	II.	Nos. 10 to 13	One	$238,200	$3,200	$3,000	$10,500	.....
Union Iron Works	I.	Nos. 10 to 13	One	246,000	3,000	3,200	10,000	.....
Union Iron Works	I.	Nos. 10 to 13	Two*	240,000	3,000	3,200	10,000	.....
Detroit Dry Dock Co.	I.	Nos. 10 to 13	One	215,750	2,250	1,000	2,500	.....
Detroit Dry Dock Co.	I.	Nos. 10 to 13	Two	429,000	2,250*	1,000	2,500	.....
Bath Iron Works	I.	Nos. 10 to 13	Two*	229,400	.....	.....	.....	.....
J. H. Dialogue & Son	I.	Nos. 10 to 13	Two	460,000	.....	.....	.....	.....
Union Iron Works	I.	Nos. 14 and 15	One	215,000	3,000	3,200	.....	$10,000
Union Iron Works	I.	Nos. 14 and 15	Two*	209,900	3,000	3,200	.....	10,000
Detroit Dry Dock Co.	I.	Nos. 14 and 15	One	213,750	2,250	1,000	.....	2,500
Detroit Dry Dock Co.	I.	Nos. 14 and 15	Two	425,000	2,250*	1,000	.....	*2,500
J. H. Dialogue & Son	I.	Nos. 14 and 15	Two	460,000	.....	.....	.....	.....

* Each.

The contracts were awarded in November for the two twin-screw gunboats, *Nos. 14* and *15*, to the Union Iron Works, San Francisco, Cal.; for two of the single-screw boats to the Bath Iron Works, Bath, Maine, and for one each to Messrs. J. H. Dialogue & Son, Camden, N. J., and the Crescent Ship Building Co., Lewis Nixon, Elizabethport, N. J.

It having been decided that the treaty agreement with Great Britain would not permit the building of a warship on the Lakes, the bid of the Detroit Dry Dock Company was rejected.

Torpedo Boats Nos. 6, 7 and *8*.—Bids for the construction of these boats, described on page 583 of the last number of the JOURNAL, were opened at the Navy Department on September 10.

The act authorizing the construction of these boats provided that one of them should be built on the Pacific Coast, one on the Mississippi River and one on the Gulf, unless it was found that they could not be built at these places.

Four bids were received on the Department's plans and specifications:

Union Iron Works, San Francisco, one for $175,000.

Union Iron Works, San Francisco, two for $173,000 each.

Union Iron Works, San Francisco, three for $172,000 each.

Wolff & Zwicker Iron Works, Portland, Oregon, one for $168,700.

Moran Brothers, Seattle, Washington, one for $163,350.

The Herreshoff Mfg. Co., of Bristol, R. I., bid on their own plans for one or all three boats at $144,000 each.

The contract for torpedo boats Nos. 6 and 7 was awarded to the Herreshoff Co. and for *No. 8* to Messrs. Moran Brothers.

The trial speed of the Herreshoff boats is to be 27½ knots for two hours with a dead load of 27.32 tons. If this speed is not reached, but is above 26½ knots, the boats will be accepted at a reduced price at the rate of $10,000 per knot below 27½.

The trial speed of torpedo boat *No. 8* is to be 26 knots for two hours with the same dead load, 27.32 tons. Similar penalties for a trial speed between 25 and 26 knots are provided.

ARGENTINE REPUBLIC.

Buenos Aires.—The following description is taken from "Engineering," London:

On Saturday, November 2, the trial was made in the North Sea off the Tyne of a cruiser Messrs. Armstrong, Mitchell & Co. have lately constructed for the Argentine Government. The trial resulted in a very remarkable performance, but before giving details of this it is well we should describe the vessel.

The *Buenos Aires* is a twin-screw, steel built, sheathed cruiser. Her building was commenced on February 2, 1893, and she was launched on May 10, 1895. She is 396 feet long between perpendiculars and 424 feet long over all. Her extreme breadth is 47 feet 2 inches. Her mean draught on trial was 18 feet 3 inches, at which the displacement was 4,740 tons. The estimated power with forced draft was 17,000 indicated horse power. The full complement of coal is 1,000 tons. The vessel is flush decked, but has a bridge forward and aft, connected by a flying gangway.

There is a conning tower forward protected by 6-inch armor, and the protective deck is 1½ inches thick on the flat and 3 inches on the slopes, but 5 inches thick over the machinery space. There are two masts, having fighting tops about 15 feet above the deck. There are also light tops above with a rail; these serving for look-out purposes. The armament is exceptionally powerful. There are, firstly, two 8-inch quick firing guns placed forward and aft respectively on the center line of the ship. These are protected by armored shields, which revolve with the guns. These two guns are mounted forward and aft of athwartship screens, which rise above the upper deck, and above which are the bridges. The upper deck, between these two screens, carries the majority of the guns. At each corner of the central battery thus formed is a 6-inch quick firing gun; thus there are four 6-inch guns on the broadsides. In the central battery there are also on each broadside six 4.7-inch quick firing guns. The smaller guns consist of sixteen 3-pounder quick firing guns and eight 1-pounder guns. Two of the 3-pounders are mounted on each bridge. There are five torpedo discharging tubes, one being through the stem, and the other four, two on each broadside. All are above water.

The accommodation for officers is extensive and well arranged, consisting of a spacious wardroom amidships, and a large room aft for the captain, or admiral if the vessel is used as a flagship. The officers' cabins are arranged on each side on the main deck. Two long passages extend nearly the whole length of the ship on the main deck. The crew are berthed forward in the usual way. The whole arrangements give an impression of roominess and comfort, indicative of a thoughtful and well planned distribution of space.

The machinery has been supplied by Messrs. Humphrys, Tennant and Co., of Deptford, a firm which has been associated with Elswick in so many of their triumphs of warship construction. The engines are of the usual type, being three-stage compounds, and having four cylinders, respectively 40 inches, 60 inches, and two of 66 inches each, the latter, of course, being the low pressure cylinders. The stroke is 36 inches. The boilers are of the ordinary return tube type, four being double-ended, and four

single-ended. The tubes are fitted with the screwed ferrule which Messrs. Humphrys have introduced, and which answered most satisfactorily on Saturday's trial.

As already stated, the ship is sheathed. She was not originally designed as a sheathed vessel, the teak and copper covering being added after some progress had been made in the construction. As the Argentine Government has not the command of graving docks, the sheathing is a necessity. Naturally it takes somewhat from the speed of the vessel, as the sheathing, with its fastenings, being approximately the same specific gravity as water, nothing is gained in carrying power, whilst the bulk of the vessel is considerably increased. There is no doubt, however, but that the sheathing will add to the average speed of the vessel when on her station; as the luxuriant growth of weeds that flourishes on the bottoms of unsheathed vessels in a warm country, takes greatly from speed. The stem and stern frames are of manganese bronze, which material is used in the construction of the rudder, and also in the two three-bladed propellers.

The now usual form of ram is adopted. It would appear, at first sight, to those unaccustomed to the consideration of problems in naval architecture, that this blunt spur must detract from the speed of the ship. It must be remembered, however, that the spur is several feet below the surface of the water, so deep that no appreciable wave making resistance is set up. The conditions of resistance, therefore, more nearly approach those of a fish, or, to use a more apposite simile, those of a fish torpedo. It will be remembered that the early Whitehead torpedoes were made pointed at the fore end, but it was found that a fuller head was actually conducive to speed. For the same reason the propeller shaft brackets are made pear shape in horizontal section, the blunt part being forward; for though the below water position of these parts prevents appreciable wave making, eddy making is not to be neglected, water being far from a perfect fluid. Our fathers would have been right in their "cod's head and mackerel-tail" theory of naval construction if they had had to do only with submerged bodies; but surface waves somewhat upset the principle when applied to vessels.

The stern is formed with deadwood cut away. The cutting up of the stern part results in giving the ship excellent manœuvring powers, as was well shown during the trials when the ship turned at the ends of the miles; although no official turning trials were made. The rudder is partially balanced. The weight is taken by the pintle and stern post in the usual way.

The *Buenos Aires* had been taken from Elswick to Jarrow previously, and on Saturday last the trial party left Newcastle at an early hour, but fog prevented the start. Shortly after midday a start was made, and the ship, attended by her two tugs, proceeded down the river and to the measured mile, which is just north of Tynemouth. There were on board the members of the Argentine Commission and Mr. Guillermo Lauder, who will be engineer-in-chief of the ship. Mr. P. Watts, chief of the Elswick shipyard; Mr. Perrett, of the constructive department, and Mr. Magnus Sandison, engineer, represented the contractors. Mr. R. Humphrys and Mr. T. Soper were in charge of the machinery, representing Messrs. Humphrys, Tennant and Co.

The time being short, it was determined only to run the six-hours' trial with natural draft. It was settled at once to make the mile runs, and thus get the data, by means of the revolutions, necessary to determine the ship's speed in the straight out-and-home run. We are not aware what was the contract speed, but in any case it was so far exceeded that it became a matter of small importance.

The following are the times for the six runs:

	Min.	Sec.	Speed.
First run, ...	2	47½	21.493
Second run, ...	2	34	23.377
Third run, ...	2	41	22.360
Fourth run, ...	2	33	23.529
Fifth run, ...	2	39	22.642
Sixth run, ...	2	37	22.930

It will be thus seen that the first two runs gave, as a result, a slower speed than the remaining four, their mean being 22.435 knots. This is accounted for by the fact that the engineers had

not time to work up to full power before going on the mile. It would have been preferable to have thrown the first two runs out and have made two more, but the contractors saw they had plenty in hand, and time was pressing. As the trial progressed additional power was developed, the revolutions increasing, and the ultimate result was a speed for the whole six hours of 23.202 knots; a performance which puts the *Buenos Aires* at the head of the sea-going ships of the world for speed of steaming. The air pressure during the trial never exceeded $\frac{4}{10}$ inch, and for some time the stokeholds were open. There was no lack of steam, as was shown by the fact that the safety valves were blowing steam hard at one part of the trial, and indeed the dampers had to be put up for a time. The boiler pressure was 155 pounds to the square inch, and the vacuum between 28 inches and 29 inches. The mean revolutions for both engines averaged 151 per minute. The indicated horse power was approximately 14,000. At the end of the trial, which was not completed until after dark, the ship returned to her moorings off Jarrow. The engines ran perfectly throughout, and there was no trouble of any sort from the boilers. What the ship would do with forced draft one can only speculate upon. The engines were linked up during the trial, but if they were given full steam, and the boilers were pressed, another knot would be doubtless a moderate estimate to put on the speed.

By the trials of the *Buenos Aires*, an English built ship once more stands first in regard to speed, putting aside torpedo craft. The pride of place has for some time been held by the United States cruiser *Minneapolis*, a vessel which made 23.073 knots on a run of 88 nautical miles. The *Minneapolis*, however, ran with an inch air pressure, and, we believe, is not sheathed; the latter condition being, perhaps, a quarter of a knot in her favor. She is 411 feet 7 inches between perpendiculars, or 414 feet 10 inches over all, her width being 58 feet 2 inches, so that she has a ratio of length to beam of 7.08, whilst that of the *Buenos Aires* is 8.39. The *Minneapolis* has three screws, a fact looked on as advantageous to her by her designers. Her main engines developed 20,366

indicated horse power on trial, the mean revolutions being 132.4, the steam pressure 148 pounds.

It will be remembered that the *Yoshino*, also built at Elswick, and of which ship we heard a good deal lately, made 23.03 knots on four runs with forced draft, thus coming very near the speed of the *Minneapolis*. That her designers have been able to produce a ship to beat the latter vessel is a fact of which they may be justly proud.

AUSTRIA.

Buda-Pesth.—This vessel, the last one of the three coast defence vessels of the *Monarch* class to be laid down, and now building at Trieste, is to have Belleville water tube boilers. The *Monarch* (described on page 417 of this year's May number) and the *Wien* have cylindrical boilers. The Belleville boilers, ordered from Messrs. Maudsley Sons and Field, are to have 720 square feet of grate surface and 22,500 square feet of heating surface and to supply steam enough for the engines to indicate about 8,400 horse power under natural draft. The I.H.P. of the *Monarch* is 8,380 under forced draft.

Wien.—The second of the *Monarch* type of coast defence vessel was launched at Trieste, July 6. For data of this vessel see *Monarch*, page 417 of this year's May number.

CHINA.

Fei Ying.—This torpedo cruiser, of 850 tons displacement, was launched in July by the Vulcan Company, at Stettin, Germany. There are eight Yarrow water tube boilers with straight tubes. The engines were built by the Vulcan Company. During the full power trial in September, she made 22 knots for four hours with 4,500 I.H.P., the air pressure being $\frac{3}{4}$ inch.

CHILI.

This Government has placed with Messrs. Laird Bros., of Birkenhead, an order for four 30-knot torpedo destroyers.

ENGLAND.

Magnificent.—This battleship, fully described on pages 161–167 of this year's February number, has completed her speed and coal

consumption trials with the following results. It is to be noted that the mean draughts on trials were very much less than the draught, 27 feet 6 inches, with 900 tons of coal, which corresponds to a displacement of 14,900 tons. With full load, and 1,800 tons of coal in bunkers, the mean draught is probably about 29 feet.

Speed trials.	*Natural draft.*		*Induced draft.*	
Date of trial	Aug. 29, 1895.		Aug. 31, 1895.	
Duration, hours	8		4	
Mean draught, feet and inches	24–11½		24–8½	
Speed, knots, by patent log	16.5		17.5	
	Starboard.	*Port.*	*Starboard.*	*Port.*
Revolutions per minute	95.48	96.51	99.8	100.8
Vacuum, inches	26.3	26.8	26.0	26.6
I.H.P., each engine	5,026	5,275	6,002	6,155
both engines	10,301		12,157	

The designed powers were 10,000 and 12,000 respectively.

The coal consumption trials were run under natural draft on September 3 and 4, 1895, for 30 consecutive hours, the I.H.P. being limited to 6,000. The average steam pressure was 133 pounds per square inch; revolutions, 82 per minute; I.H.P., 6,086; speed, 14.65 knots; and the coal burned, 1.69 pounds per I.H.P. per hour. The weather was very favorable.

From the time this ship was laid down on December 18, 1893, to the date of her steam trials is only 20⅓ months, a very noticeable feat in battleship construction.

Majestic.—This vessel, described on page 167 of this year's February number, has had her speed and coal consumption trials.

Speed trials.	*Natural draft.*		*Forced draft.*
Date of trial	Sept. 12, 1895.		Sept. 17, 1895.
Duration, hours	8		4
Mean draught, feet and inches	24–11¾		.....
Speed, knots, by patent log	16.9		17.8
	Starboard.	*Port.*	
Revolutions per minute	100.7	100.3	106
Vacuum, inches	27	26	.....
I.H.P., each engine	5,254	5,164	.....
both engines	10,418		12,497
Air pressures, inches of water	.....		0.9

Coal per I.H.P. per hour was 2.07 on the natural draft trial.

In going out for her coal consumption trial in the latter part

of September, the ship ran on a sand bank. The condensers were filled with sand and the trial was abandoned. After overhauling, the 30 hours' coal consumption trial was concluded on October 20, the ship running about 440 miles. The I.H.P. developed was 6,075, with a coal consumption of 1.84 pounds per I.H.P. per hour.

Prince George.—This first-class battleship, a sister ship to the *Majestic*, was launched at the Portsmouth dockyard on August 22. The machinery is by Messrs. Humphrys, Tennant and Co.

Victorious.—Another sister ship of the *Majestic* was launched at the Chatham dockyard on October 19.

The following is given in the London *Times* as the distribution of weights: Steel in hull, 4,560 tons; wood in decks, &c., 570 tons; fittings, 820 tons; armor, with its teak backing, 3,025 tons; protective plating, 1,250 tons; machinery, 1,320 tons; armament, 1,550 tons; general equipment, 740 tons.

As the *Victorious* is the largest and heaviest ship that has been built in this dockyard on a slip—other big vessels of her class having been built in dock and floated out—additional precautions had been taken to insure her taking the water successfully. The launching weight, as stated, was 5,460 tons, and it was said that the weight per square foot on the ways was 2½ tons. The weight of the cradle was 300 tons, so that the total weight on the ways was 5,760 tons.

The machinery was built by Messrs. Hawthorn, Leslie and Co., Newcastle-on-Tyne. The coal capacity in bunkers is 1,890 tons, 826 tons in lower bunkers, 424 in wing bunkers, and 640 on the protective deck. The total grate surface is 821 square feet and the total heating surface, 25,826 square feet.

Andromeda.—This first-class cruiser has already been described generally on page 418 of this year's May number. The hull is building at the Pembroke Dockyard. The protective deck will be 4 inches thick, arching from 6 feet below normal water line at the ship's side to 3½ feet above it in the center; abreast of the engines it will be carried up to the level of the tops of the cylinders.

Two of the fifteen 6-inch guns will be mounted on the fore-

castle and one on the upper deck aft, and will be protected by shields. The remaining twelve 6-inch guns will be in armored casemates, six on a side, four of these guns having a direct ahead and four a direct astern fire. The forward mast will have two military tops, each with 3-pounder guns; the other or mainmast will have one military top with one 3-pounder gun.

The twin-screw engines, for which the contract has been awarded to Messrs. Hawthorn, Leslie & Co., Newcastle-on-Tyne, will be of the four-cylinder, triple-expansion type, each with one H.P., 34-inches, one I.P., 55½-inches, and two L.P. cylinders, 64 inches in diameter. The stroke will be 4 feet. The engines are to make 110 revolutions per minute, equal to a piston speed of 880 feet per minute. The I.H.P. will be 16,500, and 20,000 if the draft is forced.

There will be thirty water tube boilers of the Belleville type, which are also to be built and supplied by the Messrs. Hawthorn. The total grate surface will be 1,450, and the total heating surface about 46,000 square feet. They will generate steam of 300 pounds pressure, which will be reduced to 250 pounds per square inch at the engines.

The estimated weight of the machinery is said to be 1,540 tons.

Diadem.—Sister ship to *Andromeda*. To be built by the Fairfield Shipbuilding & Engineering Co., Govan.

Europa.—Sister ship to *Andromeda*. To be built by Messrs. J. & G. Thomson, Clydebank.

Niobe.—Sister ship to *Andromeda*. To be built by the Naval Construction & Armaments Co., Barrow-in-Furness.

Arrogant.—This second-class cruiser, of which a general description was given on page 419 of this year's May number, is building at Devonport Dockyard. The contract for the machinery has been awarded to the Earle Ship Building Co. There are to be 18 Belleville boilers, having 4½-inch tubes. The total grate surface is to be 867 square feet, and the total heating surface, 26,000 square feet. The steam pressure in boilers will be 300 pounds per square inch, which will be reduced to 250 pounds at the engines.

Furious.—This cruiser, a sister ship to the *Arrogant*, is building at the Portsmouth Dockyard. The machinery is to be built by the Earle Ship Building Co.

Venus.—This second-class cruiser of the *Talbot* class (a general description of which was given on page 427 of this year's May number), was launched by the Fairfield Shipbuilding and Engineering Company, Govan, on September 5. The vessel was put into the water 240 days from the date of the order being placed. She is constructed of Siemens-Martin steel and sheathed with teak. In order to steady her for sea, she is provided with bilge keels of considerable length. There is a protective steel deck with a thickness varying from 1½ to 3 inches. A Harveyized steel coaming protects the engines. The conning tower is of the same material. There are 3 torpedo tubes, two forward under water and one aft above water. A speed of 20 knots is expected. The high pressure cylinders have piston valves, and the others double-ported slide valves, and the cylinders are separate castings. Steam of 155 pounds pressure is supplied from eight single-ended boilers, each with three furnaces. They are placed in two separate compartments, and fitted to be worked under forced draft with closed stokeholds.

Minerva.—This second-class cruiser, the general particulars of which were given on page 516 of Vol. V, was floated out of dock at the Chatham Yard on September 23. The keel was laid on December 4, 1893.

Proserpine.—This third-class cruiser, some data of which were given on page 419 of this year's May number, is to have Thornycroft boilers. The machinery of this vessel is building at the Devonport Dockyard and the hull at the Sheerness Dockyard.

Hermione.—This is one of the sheathed cruisers built at the Devonport Dockyard, under the Naval Defence Act, and launched November 7, 1893. The machinery was built by Messrs. J. & G. Thomson, Clydebank. Recently the ship underwent a series of steam trials which, in comparison with the contract trials, are interesting. These trials were to be run from Plymouth to Falmouth and back, one at 7,000 I.H.P. under natural draft, and another at 9,000 I.H.P. under forced draft. The results of these

runs are given in the columns headed "Service," and the contract results have been added for reference.

	Natural draft.		Forced draft.	
	Contract.	Service.	Contract.	Service.
Date of trial.....	May 10, 1894.	August, 1895.	May 12, 1894.	August, 1895.
Length of trial, hours.....	8	4	4	2
Pressure in boilers.....	140	140	144	152
Pressure at engines.....	.....	134	.....	147
Revolutions per minute....	128.7	126.4	137.4	134.25
Vacuum, in inches	26.3	25.3	26.8	24.75
I.H.P	7,393	7,207	9.264	9,044
Speed by patent log.....	.....	18.3	19.5	18.95
Air pressure, inches.....	0.45	0.42	0.94	1.1

On the above forced draft trial, the P.I.P. valve rod heated and the engines were slowed for a short time; but for this, the mean speed would have been greater than 18.95, as a speed of 19.3 was made during a part of the trial.

The displacement on these trials exceeded that on the contract trials, and the bottom was not clean.

In addition to these trials, a series of sixteen progressive runs, four at 10, four at 13, four at 16 and four at 18.5 knots were made. Besides, two runs were to be made at the slowest possible speed, and two at full power under forced draft.

Most of these progressive trials were satisfactory, but no results have been published. Just before starting on the forced draft runs, 9,000 I.H.P., one of the I.P. slide valve rods was found to be bent. Further examination showed that a new valve would have to be made and several other defects would have to be repaired.

After repairs, one forced draft run was made, but the results were not considered satisfactory. The steam pressure was 155 pounds in boilers and 148 at engines, the mean I.H.P. being 9,195 and the speed, by log, 19.75. This was nearly the same speed attained a few days previously with about 7,000 I.H.P.

In October the machinery was examined and the slide valves

were found so unsatisfactory that the ship was paid off and laid up for repairs.

Salmon.—This torpedo boat destroyer, which is one of the two vessels built and engined by Earle's Shipbuilding and Engineering Company, of Hull, made her official trial at the mouth of the Thames on Monday, July 29. The following account is taken from "Engineering," London. The trial was made under the superintendence of Lord Charles Beresford, Captain of the Medway Dockyard Reserve, Mr. J. Pledge and Mr. J. Harding representing the Admiralty. Mr. Dixon conducted the trials on behalf of the contractors. The *Salmon* is one of the larger type of torpedo boat destroyers, being 200 feet long and 19 feet 6 inches wide. The displacement in sea-going trim is 253 tons. The twin-screw engines are of the usual three-stage compound type, having cylinders 19¼ inches, 28½ inches and 43 inches in diameter, the stroke being 18 inches. The specified weight for all machinery, including water in boilers, condensers, fittings, &c., was 125 tons, but Mr. Seaton has, we believe, been able to keep within this limit. The boilers are of the Yarrow type, being similar in general design to those placed by Messrs. Yarrow & Co. in the *Hornet*. They are reported to have worked in a perfectly satisfactory manner throughout the trial. It will be seen by the accompanying details of the trial that for the first four runs on the mile the speed was about 28 knots, whilst the mean speed on the usual three hours' run was 27.608 knots. This is a very good performance considering the comparatively small power developed. The following are the details of the official trial:

Date of trial	July 29, 1895.
Nature of trial	3 hours, full power forced draft, contractors'.
Draught of water { forward, feet	5
Draught of water { aft, feet and inches	7–3
Mean speed of ship, knots	27.608
Steam pressure in boilers, pounds per square inch	177
Air pressure in stokeholds, inches of water	2.62

	Starboard.	*Port.*
Vacuum in condenser	23.5	24.3
Revolutions per minute	354 5	355.25

Mean indicated horse power:	*Starboard.*	*Port.*
High	553	491
Intermediate	586	653
Low	647	659
Total, each engine	1,786	1,803
Both engines	3,589	

Details of the trial:	*Revolutions.*	*Speed, knots.*
First mile	363.6	27.565
Second mile	363.3	28.125
Third mile	363.0	28.125
Fourth mile	360.7	27.907
Fifth mile	354.4	27.692
Sixth mile	351.7	26.946
Admiralty mean	.....	27.88

Total revolutions for three hours:	*Starboard.*	*Port.*	*Mean starb.*	*Revs. port.*
First half hour	10,802	10,734	.....	.....
First hour	21,259	21,216	.....	.....
1½ hours	32,142	32,017	.....	.....
2 hours	42,857	42,771	354½	355¼
2½ hours	53,462	53,472	.....	.....
3 hours	63,817	63,943	.....	.....

Mean speed 3 hours, 27.608 knots.

Starfish.—This torpedo boat destroyer, built by the Naval Construction and Armaments Company, Barrow-in-Furness, ran her official speed and steering trials on the Clyde on October 7th. The vessel is 190 feet long, 19 feet beam, and at 5 feet 7 inches draught displaces 252 tons. The engines are triple expansion, with cylinders 18, 27 and 42 inches in diameter by 18 inches stroke. There are four Blechynden water tube boilers working with a pressure of 200 pounds to the square inch. The grate surface is 170 square feet. The weight of propelling machinery complete, with water and spare gear, is 104.75 tons. The contract stipulated that the vessel should maintain a speed of 27 knots on a trial of three hours' duration with a deadweight of 30 tons on board, the revolutions of the engines necessary to give the speed being determined by running the vessel six times over the measured mile. As a mean of these six runs, the *Starfish* obtained a speed of 27.87 knots, while the remaining and longer part of the

trial was run at a speed of 28.05 knots, making the mean of the whole three hours 28 knots, or one knot in excess of the guarantee. The mean revolutions of the engines on the three hours' run were 407 per minute, and the I.H.P. 4,510. The amount of coal consumed on the three hours' run was 15 tons 2 cwt., a most creditably small consumption per horse power for forced draft and water tube boilers. If the speed had been kept down to the guaranteed speed of 27 knots, the consumption would have been reduced to between 12 and 13 tons, which is a most excellent result. This coal consumption is said to be less than for any of the other British destroyers. The speed on mile runs was as follows:

Run.		Mean of Means.	Revolutions.	
1.	27.692		405.2	
2.	28.082		400.2	
3.	27.650	27.87	406.9	406.24
4.	27.907		405.6	
5.	27.907		413.9	
6.	28.082		399.2	

During the whole trial the steam pressure was easily and constantly maintained, and there was no objectionable discharge of flame from the smoke pipes.

The 12 hours' coal consumption trial proved highly satisfactory, although the weather was somewhat boisterous, and there was a very confused sea. A speed trial was made on the measured mile at Wemyss Bay to ascertain the revolutions corresponding to 13 knots, the speed at which the coal consumption was to be determined; the result was: Speed, 13.278 knots; revolutions, 169.56. The vessel afterwards cruised down the coast of Arran and in the neighborhood. The coal was weighed at the bunker doors by the representatives of the Admiralty and the contractors. The conditions of the fires, and the levels of the water in the boilers and feed tanks, were noted at the commencement of the trial, and left in the same condition at the end. The revolutions of the engines were taken by the counters every hour, as also were diagrams from the engines. Steam was maintained at 180

pounds per square inch. The results of the twelve hours' trial were as follows: Speed, 13.03 knots; revolutions, 166.37 per minute; indicated horse power, 400.4; total coal consumed, 8,906 pounds; knots steamed per ton of coal, 39.32. Before commencing the trial a portion of the grate surface was covered with clinker. At the end of the fifth hour still more of the grate surface was covered. During the remaining seven hours of the trial, the results were much improved, being: Speed, 13.11 knots; revolutions, 167.245 per minute; indicated horse power, 402.3; coal consumed in seven hours, 4,599 pounds; knots steamed per ton of coal, 44.8; coal burnt per indicated horse power, 1.635 pounds per hour. The results for both the 12 and 7 hours are said to be better than any hitherto recorded in vessels of this class built for the British Navy, the highest previous record being about 38⅛ knots per ton of coal. As this vessel has a bunker capacity of 70 tons, she will have a radius of action at 13 knots speed of 2,800 miles at least, which will compare very favorably with many large vessels. The observations made while rolling broadside on the sea gave the time of complete oscillation as from 4.4 to 4.8 seconds.

It has been decided to replace the copper tubes in these boilers by steel tubes.

Quail.—One of four 30-knot torpedo boat destroyers building by the Messrs. Laird Bros., Birkenhead, was launched on September 24, 1895, eighty-eight days after the laying of the first plate. The displacement is 300 tons and the I.H.P. 6,000. The armament consists of one 12-pounder, five 6-pounders, and four 18-inch torpedoes. There will be two revolving torpedo tubes.

Sparrowhawk.—The second of the above Laird-built torpedo boat destroyers was launched on October 8, one hundred days after the laying of the first plate. The two remaining destroyers are to be named *Thrasher* and *Virago.*

30-Knot Torpedo Boat Destroyers.—Besides the four destroyers mentioned above, the *Desperate*, *Fame*, *Foam* and *Mallard*, are constructing by Messrs. Thornycroft & Co., Chiswick. Their displacement will be 272 tons, and the I.H.P., 5,400. Messrs. J. & G. Thomson, Clydebank, have the contract for the *Brazen*, *Electra*, *Recruit* and *Vulture*. Their displacement will be 300

tons and the I.H.P., 5,800. The armament is the same as that of the Laird destroyers.

Lynx.—After the accident by grounding (an account of which was given on page 170 of this year's February number), and the completion of the consequent repairs, a full power trial was undertaken in July. While the engines were developing about 3,500 I.H.P., a tube exploded in the forward water tube boiler (modified Normand type), happily without injuring any one, and the trial was stopped. Later, further defects were discovered. After repairs, a satisfactory trial was completed on August 7, the mean results of which are: Steam pressure at engines, 152 pounds per square inch; vacuum, 26 inches; revolutions, starboard engine, 309.3 and port engine, 303.4; I.H.P., starboard engine, 1,858, and port engine, 1,685; total I.H.P., 3,543; air pressure, 3.6 inches; speed by patent log, 22.2 knots.

She is now to be commissioned at Devonport Dockyard for the training of the engineer's force in the management of water tube boilers. Her complement of officers and men for this purpose will be forty-two.

Banshee and *Ferret.*—These torpedo boat destroyers (the former described on page 424 of the May number, and the latter on page 613 of Vol. VI), are to be commissioned for the same training purposes as the *Lynx*. The complement of officers and men of the *Banshee* will be fifty.

Spanker.—This torpedo gunboat has had her old boilers replaced by four water tube boilers of the DuTemple type. Each boiler has 736 tubes. These boilers were bought in France and put in the ship by the dockyard force. Before they left the makers' works, they were tested to 280 pounds per square inch by hydraulic pressure and 154 pounds per square inch steam pressure. Each boiler is to be tested separately for four hours for evaporative power, the contract requiring that each boiler shall supply, for the four hours, 8.8 tons of dry steam at 155 pounds pressure, with an air pressure not exceeding 4 inches of water.

The weight of the boilers without water is estimated at 12.3 tons, and including water, at 15.25 tons. About $30,223 was

paid to the manufacturers for the boilers, and about $65,823 has been expended by the dockyard in fitting the boilers on board.

This vessel, built in 1890, at a total cost of about $262,658, has since cost for maintenance and repairs (including the new boilers) about $109,395, although she has never seen service beyond the naval manœuvres in home waters.

The new boilers were tested for evaporative efficiency and coal consumption with satisfactory results in August, but no data have been published.

A series of trials, similar to those with the *Sharpshooter*, are to be undertaken with this vessel.

Sharpshooter.—The four series of trials mentioned on page 601 of the last number, were satisfactorily completed in October. At the end of the eighth trial, a cracked L.P. cylinder head besides minor defects were discovered. Further trials are to be made, one of eight hours with the six after boilers, the engines indicating 2,300 H.P., and another of four hours, with the same boilers, at 2,800 I.H.P. Then trials in suddenly stopping and starting when running at full speed, and in starting and stopping at intervals. Also, to lie under banked fires for four hours and then go ahead at full speed and be manœuvred as if in action. These trials are all to take place sometime in November, in the channel off Plymouth, after docking and making good the various defects caused by the previous series of trials.

After these trials are completed, the *Sharpshooter* will be used as a training ship for the men of the engineer's force, more especially for those who are to serve on the *Powerful* and *Terrible*. It is hoped that in nine months a sufficient number of men can be trained in the use and care of Belleville boilers for this purpose.

Sturgeon.—This torpedo boat destroyer, the trials of which were noted on page 425 of this year's May number, and on page 602 of the August number of the JOURNAL, is to have the copper tubes in her boilers replaced by steel tubes.

Sunfish.—This torpedo boat destroyer, which has been designed, built and engined by Messrs. R. and W. Hawthorn,

Leslie and Co., had a second preliminary trial on August 1 prior to leaving for Chatham. The mean speed attained, with full load on board, on six runs was 27.24 knots with an air pressure of 2½ inches, the revolutions being 340. The vibration was slight. The boilers are of the Yarrow type. Both engines and boilers worked splendidly.

Haughty.—This torpedo boat destroyer was launched from the shipbuilding yard of Messrs. Doxford and Sons, Sunderland, in the presence of several thousands of spectators. She is built on the most approved lines, is 196 feet in length, 19 feet broad, and 12 feet 6 inches deep. Her designed speed is 27 knots. She will carry a complement of about 50, a 12-pounder quick firing gun, and five six-pounders.

FRANCE.

Charlemagne.—This battleship, described on page 427 of Vol. VI, was launched at Brest on October 5.

Designed by M. Thibaudier, director of the arsenal at Rochefort, she was intended to be one of three battleships of a new type, her sisters being the *Saint Louis* and *Henry IV;* but the last named has been designed afresh upon a smaller displacement. The length of the *Charlemagne* (385 feet 6 inches) exceeds that of any other French battleship yet afloat, and she is built upon finer lines than her predecessors, her beam being 67.26 feet. The dimensions of the *Jaurèguiberry* are 356 feet and 72 feet 8 inches. This new character, which permits greater possibilities of speed, is made possible by a redistribution of the armament. In recent French battleships the heavy guns have been placed singly in turrets or barbettes, two in the keel line of the ship, fore and aft, and one on each beam; but in the *Charlemagne* and her sister—as well as in the *Gaulois*, which is to be laid down on the slip which the first of these vacates—the English system of coupled guns has been adopted. Four 11.81-inch guns are thus to be mounted, in two closed turrets well above the water line, for the vessel has high freeboard, the type of the *navire à plage*—of which the *Hoche* is an example—being now definitely abandoned.

The rest of the armament and the armor protection and machinery have already been described.

Foudre.—This torpedo transport or depot ship, the construction of which was commenced in 1892, and a general description of which was given on page 126 of Vol. IV, was launched by the Chantiers de la Gironde, at Bordeaux, on October 20. As this vessel is to serve the same purpose as H. M. S. *Vulcan*, a comparison of the two will be interesting.

	Foudre.	*Vulcan.*
Length, feet and inches	370–9	350
Beam, feet and inches	52–6	58
Draught, aft, feet and inches	23–5½	23
Displacement, tons	5,876	6,630
I.H.P	11,244	12,000
Speed, knots	19	19
Coal carried, tons	850	1,000
Armament, all rapid fire guns	10, 3.9-in.; 4, 2.5-in.; and 4, 1.45-in.	8, 4.7-in.; 12, 3-pounders.
Torpedo boats carried	10	9

The *Foudre* is furnished with powerful apparatus for hoisting in and out the ten vedette torpedo boats which she is to carry upon her deck, and which are all built of aluminum. Several of them are ready or in hand, and five more are to be built in 1896. The pattern boat was constructed by Messrs. Yarrow Co., and attained a mean spead of 20.56 knots at the mouth of the Thames in September, 1894. She displaced 14 tons, and was 62 feet 4 inches long, with a three-cylinder engine and Yarrow boilers, but was built of French materials. By the use of the lighter material a saving of 2 tons was effected on a total weight of 9½ tons, including machinery.

It will be noticed that the *Foudre* has very much finer lines than the *Vulcan*, although a slightly greater draught. Whether the lighter boats and consequent lighter hoisting apparatus will justify the greatly decreased beam of the *Foudre* and make the hoisting in and lowering of the torpedo boats safe in a moderate sea-way remains to be seen.

Chateaurenault and *Guichen.*—These are the new rapid cruisers, a general description of which was given on page 602 of the last number. There will be three screws, each driven by an engine of about 8,000 I.H.P., the estimated speed being 23 knots. There will be 36 water tube boilers in six compartments, forward and aft of the engines.

Jurien-de-la-Gravière.—This sheathed second-class cruiser is to be commenced at Cherbourg. She will be of the same type as the *Descartes*, have a displacement of about 4,000 tons and a speed of at least 19 knots.

Flibustier.—The following particulars of this sea-going torpedo boat, built by Normand, Havre, a mention of whose trial is made on page 430 of this year's May number, are from "La Marine de France":

Length on load water line, feet	137.80
Breadth, extreme, feet	14.76
Depth amidships, feet	9.84
Draught, aft (for screws), feet	7.87
of hull, at midship section, on trial, feet	4.53
Immersed midship section, square feet	47.79
Displacement on trial, tons	123.34
Speed on trial, knots	25.66
I.H.P., estimated	2,466
Coal carried on trial, tons	17

Her armament comprises one fixed tube in the stem, one swivel tube on deck just above the engines, and two 47-mm. rapid fire guns placed abaft the conning tower.

The engines are twin-screw and of the triple expansion type, and the boilers, two in number, of the DuTemple-Normand type, having a collective grate and heating surface of 66.7 and 3,078 square feet, respectively.

The weight of machinery, including water in boilers, is about 51 tons.

During the naval manœuvres last summer, she is said to have maintained a speed of 20 knots for eight hours.

Forban.—This sea-going torpedo boat, built by Messrs. A. Normand and Co., Havre, France, and designed for a speed of 30

knots, was briefly described on page 429 of Vol. VI. She was launched on July 24, 1895. Her dimensions are:

Length between perpendiculars, feet	144.36
Breadth at water line, feet	14.50
extreme, feet	15.29
Depth amidships, feet	9.96
Displacement on trial, tons	125
load, tons	136

Her armament consists of two 37-mm. rapid fire guns and two 14-inch torpedo tubes.

She is a twin-screw boat, with triple expansion engines, steam for which is supplied by two Normand boilers. The original design contemplated the use of aluminum for some of the working parts of the engine, but its use was soon abandoned. She is supplied with the Normand feed water heaters and filters; and one peculiarity of her machinery is that the condenser tubes are curved and expanded into the tube sheets.

The preliminary trial made on September 17, 1895, to determine the coal consumption at 14 knots, lasted eight hours, the resulting consumption, reduced to 14 knots, being 423.4 pounds per hour.

The official full speed trial of the *Forban* took place on the 26th of September, the load carried being 16 metric tons, or $15\frac{3}{4}$ long tons, and included torpedoes and their launching tubes, guns, coal, equipment, provisions, drinking water and electric plant. It was made as follows: At the beginning of the trial three runs were made over the measured base at Cherbourg, and the revolutions per knot noted; then a run in free route, lasting one hour, during which the revolutions of the engines were again noted; and, at the expiration of the hour, three more runs on the base, the revolutions per knot being again noted for each run. The speed in free route was then determined from the revolutions per knot on the base by taking the means of the means for each series separately, the middle run of each series entering twice in determining the mean for the series.

As thus determined, the mean speed for the one hour run in

free route was 31.029 knots, the fastest speed yet made by any boat afloat.

The I.H.P. on trial was not stated, but the *Forban* was designed for 3,200. The coal consumption was 2,695 kilos, or 5,942.5 pounds per hour.

GERMANY.

Battleship, First-class—Ersatz *Preussen.*—The principal dimensions of this new triple-screw battleship, now building, are as follows:

Length, feet	377.3
Beam, feet	66.93
Draught, feet	25.7
Displacement, tons	11,000
I.H.P.	13,000
Speed, knots	18

The armor belt will extend about four-fifths of the length of the ship, beginning at the bows. The three propellers will be specially protected by curved iron sheathing under water. The armament will consist of six 9.45-inch guns in barbettes having 12 inches of armor; eighteen 5.9-inch rapid fire guns; twenty-four other rapid firing guns; and six torpedo tubes. The central battery will be protected by 3 inches, and the conning tower by 9 inches of Harveyized steel armor.

The cost of the ship is estimated at 14,250,000 marks, exclusive of the armament, the cost of which will be about 5,000,000 marks. The time allowed for construction is four years.

Armored Cruiser, First-class—Ersatz *Leipzig.*—The principal dimensions of this sheathed steel cruiser, to be built at the dock-yard in Kiel, are as follows:

Length, extreme, feet	410.1
between perpendiculars, feet	383.9
Beam, extreme, feet	66.93
Draught, feet	25.91
Displacement, tons	10,137
I.H.P., about	13,000

The thickness of the side armor will be 7.87 inches, and that of the armored deck, from 1.97 to 3.15 inches. The armament

will consist of two 9.45-inch, 40-caliber guns; twelve 5.9 inch, and ten 3.46-inch rapid fire guns; eighteen machine guns and five torpedo tubes.

Water tube boilers will be used.

Three Protected Cruisers, Second-class.—*K*, *L*, and Ersatz *Freya*. —These steel, triple-screw cruisers, about to be commenced, will have the following principal dimensions:

Length, feet	344.4
Beam, feet	57.07
Draught, normal (500 tons of coal), feet	20.5
load (950 tons of coal), feet	21.68
Displacement at normal draught, tons, about	5,561
load draught, tons, about	6,004
I.H.P.	10,000
Speed, knots	21

The hull of one of these cruisers will be built at the Dockyard in Danzig, and the machinery by the Germania Co., of Kiel. The other two will be built entirely by contract, one by the Vulcan Co., of Stettin, and the other by the Weser Co., of Bremen.

The protective deck will vary in thickness from 2.3 to 3.9 inches, the lower end being 5 feet below, and the upper, horizontal and central part, 20 inches above the normal water line. On each side, for a length of 230 feet, there is a belt of cork, about 8¼ feet high and 27½ inches thick.

The armament will consist of two 8.2-inch, 40-caliber guns in turrets; four 5.9-inch rapid fire guns in turrets and four in armored casemates; ten 3.46-inch rapid fire guns, protected by shields; ten 1.45-in rapid fire guns; four machine guns, and three submerged torpedo tubes, one in the bow and one on each broadside.

There will be two military masts, the forward one having two and the after one a single fighting top.

These ships will be propelled by triple screws, each engine being in a separate compartment, and have water tube boilers arranged in six separate compartments.

Komet.—The trials of this torpedo cruiser, which has been under construction for several years, were recently completed and

a speed of 20.8 knots made for two hours with 214 revolutions of the engines. She was built at the Vulcan works, Stettin, and was designed for a speed of 22 knots, with 5,000 I.H.P.

Much conflicting data have been published respecting her dimensions, but the following, taken from the description accompanying her model at the World's Columbian Exposition, is believed to be correct: Length, 256 feet; breadth, 31½ feet; mean draught, 10.25 feet; displacement, 990 tons.

Her battery comprises four 3.5-inch and nine smaller rapid fire guns, and one torpedo tube.

HOLLAND.

Friesland, Holland, Zeeland.—These three steel, twin-screw, protected cruisers are now under construction. The first is to be built by the Netherlands Steamship Co., at Feijenoord; the second at the Dockyard in Amsterdam; and the third by the Schelde Co., at Vlissingen. These vessels are to be completed by the beginning of 1898. The following are the principal dimensions:

Length between perpendiculars, feet	294.3
Beam, extreme, feet	48.23
Draught, greatest, feet	17.71
Displacement, tons	3,838
I.H.P., about	9,124
Speed, knots	20

The protective deck will be made of two plates of a total thickness of 2 inches. The double bottom will extend over the greater part of the length of the vessels. The coal bunkers are abreast of the machinery, above the protective deck.

The conning tower will be of nickel steel 3.94 inches thick. Aft there will be a directing tower for the torpedoes, 2.95 inches thick.

The armament will consist of two 5.9-inch rapid fire guns, one on the forecastle and the other on the poop; six 4.7-inch and four 2.95-inch rapid fire guns on the upper deck; four 1.46-inch rapid fire guns on main deck, four on the two bridges, and four

in the tops of the two military masts; and four torpedo tubes, one in bow, one in stern and one on each broadside.

There will be either two triple or two quadruple expansion engines, to work at 145 revolutions per minute. The cylinder diameters for triple expansion engines are to be 33, 49 and 74 inches, and for quadruple expansion engines, 28.94, 39, 53.5 and 72 inches, the stroke being 39 inches.

The I.H.P., 9,124, is to be maintained during a four hours' trial with a maximum air pressure of 2 inches of water.

There will be two cylindrical and eight Yarrow water tube boilers, the working pressure of all to be about 200 pounds per square inch.

The total grate and heating surfaces of the two cylindrical boilers will be 200 and 4,000 square feet, respectively; and for the eight Yarrow boilers, about 320 and 16,000 square feet, respectively.

There will be electric lighting throughout and electric signals for interior communication.

ITALY.

Vittor Pisani.—This armored cruiser, laid down on December 7, 1892, was launched on August 14 at Castellamare. The principal dimensions are as follows:

Length, greatest, feet	346 8
Length, between perpendiculars, feet	324.8
Beam, feet	59.16
Draught, forward, feet	22.31
aft, feet	23.62
mean, feet	22.96
Displacement, normal, tons	6,397
I.H.P.	12,822
Speed, knots	20

The water line belt is of nickel steel, 5.9 inches thick and extends along the whole length of the vessel, and is surmounted, for about two-thirds the length of the vessel, by an armored citadel, also 5.9 inches thick. In this central citadel are placed eight of the twelve 6-inch guns. The vital parts of the vessel are fur-

ther protected by a curved steel deck the thickness of which varies from .87 to 1.46 inches. The conning tower is 5.9 inches thick.

The armament consists of twelve 6-inch guns; six 4.7-inch guns, four in broadside, one forward and one aft; two 2.95-inch; ten 2.24-inch; ten 1.46-inch, and several machine guns. There are five above-water torpedo tubes, one of which is in the bow.

The machinery was built by the Hawthorn-Guppy Co. of Castellamare, the twin-screw triple expansion engines being in two separate compartments. There are eight single-ended four-furnace boilers, in four compartments, forward and abaft of the engines. The working pressure in the boilers is 155 pounds per square inch.

The propellers are four bladed. The I.H.P. at natural draft is 8,482, and at forced draft, 12,822.

At normal load, the coal supply is 590 tons. The maximum amount of coal that can be carried is about 984 tons, besides liquid fuel.

The complement is 26 officers and 425 men.

Elba.—This sheathed steel cruiser, which was launched at Castellamare in 1894, has had her trials. The hull and machinery were built in Castellamare.

The following are the general particulars of the vessel and the results of her trials:

Length, feet	272.3
Beam, feet	39.37
Depth, feet	28.21
Displacement, feet	2,697
I.H.P., designed	6,411
Speed, designed, knots	18

The armament consists of seven 6-inch, six 4.7-inch, eight 2.24-inch, six 1.46-inch, two machine guns and two torpedo tubes.

The machinery was built by the Hawthorn-Guppy Co., of Castellamare.

The six hours' trial under natural draft was made off Naples on May 20, the ship's bottom being foul, with the following results:

Displacement, 2,660; mean draught, 15.35 feet; sea smooth; mean pitch of propellers, 15 feet; steam pressure in boilers, 128 pounds per square inch; average number of revolutions per minute, 135; vacuum, 26 inches; I.H.P., 4,860.8; mean speed, 15.9 knots. The temperature of the engine rooms was 123 degrees Fahrenheit, and that of fire rooms from 115 to 123 degrees Fahrenheit, with blowers running.

On May 22, a trial at very low speed and with jet condensation was made. It was found that the lowest number of revolutions at which the engines could be run was 16, while the maximum number obtainable with jet condensation and 90 pounds of steam at engines was 55, the vacuum being 24 inches.

On the 19th June a forced draft trial of 1½ hours' duration was made.

Mean draught of water, about 16 feet; sea, smooth; mean pitch of propellers, about 16 feet; steam pressure in boilers, 145 pounds per square inch; average number of revolutions per minute, 151; vacuum, 26 inches; air pressure, 2 inches; I.H.P., 7,369; mean speed, 17.9.

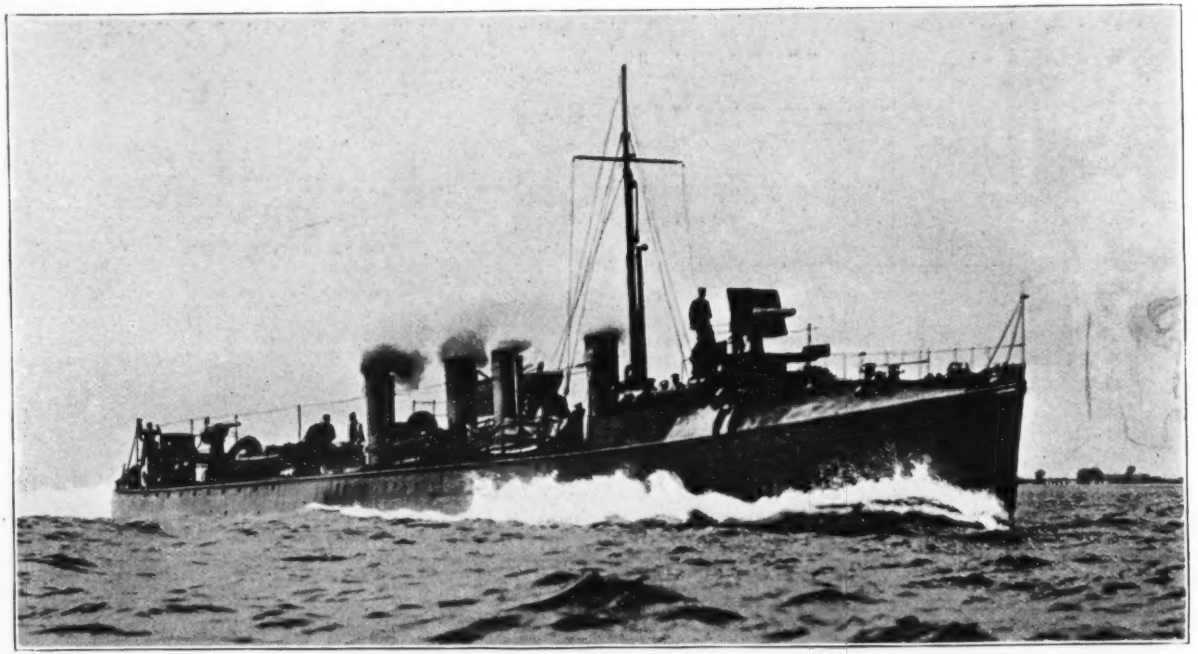
The temperature of the engine rooms ranged from 111 to 118 degrees Fahrenheit, and that of fire rooms from 122 to 136 degrees Fahrenheit.

Caprera.—This twin-screw torpedo cruiser, of which a general description was given on page 620, Vol. VI, had her trials recently.

Her designed displacement was 840 tons, and speed 20 knots, with 3,945 I.H.P., forced draft; the power with natural draft being 1,973.

On the natural draft trial, the I.H.P. developed was 2,146, the speed being 17.75 knots, and the coal consumption 1.72 pounds per I.H.P. per hour.

On the forced draft trial, the speed was not measured exactly. This trial was of 1½ hours' duration, the mean I.H.P. developed being 4,133. The steam pressure in the four locomotive boilers was 180 pounds per square inch; air pressure, 1.24 inches; the revolutions being limited to 290 per minute.



RUSSIAN TORPEDO BOAT DESTROYER "SOKOL."

BUILT BY YARROW & CO., POPLAR.

RUSSIA.

Sokol.—The following description of this fast torpedo boat destroyer is compiled from various sources. The photograph accompanying this description was kindly sent by the builders, Messrs. Yarrow & Co., Poplar.

On Thursday, August 22d, the new torpedo boat destroyer *Sokol* (Russian for Hawk) was launched from the works of Messrs. Yarrow & Co. This vessel has been built for the Imperial Russian government. She is 190 feet long, 18 feet 6 inches beam, draws 7 feet, has a displacement of 240 tons, and carries 60 tons of coal. The arrangement of the space forward, below the deck, is similar to that usually adopted in the British navy, that part of the vessel being appropriated to the crew, but in the after part abaft the engine room there is a distinct departure from British practice, the accommodation for the officers being a decided improvement on that of the *Havock* and *Hornet*, the alteration in this respect having been determined by the Russian naval authorities. She is the first torpedo boat destroyer in which nickel steel has been adopted as the material of construction. This class of steel, as is well known, has a strength exceeding that of ordinary mild steel to the extent of about 30 per cent. The engines are twin-screw, triple expansion, and indicate about 4,000 horse power. The speed guaranteed by the builders on a three hours' trial was 29 knots, carrying 30 tons. This speed was 2 knots in excess of any speed promised at the time the contract was made. Steam is supplied by eight of Yarrow's patent water tube boilers, with straight tubes. The armament is practically the same as that fitted in similar vessels in the British navy—two revolving torpedo tubes, placed on deck, for firing 16-inch torpedoes, one 12-pounder and three 6-pounder quick firing guns. As is customary at Messrs. Yarrow & Co.'s works, there was no ceremony at the time of launching the vessel. The Russian authorities, however, were represented by several officials.

She was launched with all machinery on board, and steam up in four of the boilers. After the launching, the main and auxiliary engines were at once tested under steam. The following day, Friday, the 23d, the first preliminary trial, which was pro-

gressive, as usual, took place on the measured mile at Maplin. The load carried was the contract weight of 30 tons The maximum speed, mean of the two last runs, with and against the tide, was over 30¼ knots.

Steam pressure.			Vacuum.	Air pressure in stoke-hold.	Revolutions per minute.	Time.		Speed.	Mean speed.
Boilers.	First receiver.	Second receiver.							
Pounds.	*Pounds.*	*Pounds.*	*Inches.*	*Inches.*		*Min.*	*Sec.*	*Knots.*	*Knots.*
124	48	4	24½	7/16	334	2	39	22.641	25.778
130	54	7	24½	9/16	355	2	4½	28.915	
136	54	8	24	½	364	2	22	25.352	27 802
145	60	8½	24	¾	386	1	59	30.252	
154	64	10	23	1 3/16	412½	2	10	27.692	29.363
162	67	10½	23	⅞	402	1	56	31.034	
164	71	11	22	1	410	2	6	28.571	30 285
165	72	11	22	1⅛	426	1	52½	32 000	

The Russian Government thus possesses the fastest vessel afloat. Besides the high speed, the low air pressure and the I.H.P., about 4,000, with which this speed was obtained are remarkable.

The engines are of the type ordinarily fitted by Messrs. Yarrow in vessels of this class, having cylinders 18 inches, 26 inches and 39½ inches in diameter by 18 inches stroke. There is one surface condenser having one centrifugal pump, in place of two as usual. The surface condenser is of copper; it was made by the Elmore process of electro-deposition, and has corrugations worked in the copper to stiffen it. The feed and air pumps are of the usual description. The ordinary auxiliary machinery, consisting of air compressors, an evaporator, electric light machinery for search light, is fitted. The steam steering gear is of a new design, which has been worked out specially by Messrs. Yarrow & Co., and made by them. The device for changing from steam to hand working has been much simplified, and is a very pretty arrangement. The boilers are eight in number, and

the boiler arrangements are similar to those of the *Hornet*, the vessel built by this firm for the English government, but which was about 2¼ knots slower than the Russian vessel.

The official three hours' run was made on Friday, September 6th, in the presence of several Russian naval representatives.

The *Sokol* left the Poplar yard early in the morning, and took up the trial party at Gravesend about 11 o'clock. The programme was somewhat different to that usually followed by the English Admiralty. It was arranged that three consecutive runs should be made on the Maplin mile, down, up and down, after which a straight-away run out and back of 2¼ hours should be made. At the end of this run the vessel would be on the mile again, when three more timed runs were made. The whole time occupied was exactly three hours, and during that time the usual regulations were observed, the trial being continuous. The mean speeds and revolutions of the two sets of three-mile runs were used as a basis to calculate the mean speed attained during the 2¼ hours' run from the number of revolutions made by the engines in that time. The plan of splitting the measured mile runs up into two sections is not usual, though it has advantages, as it gives more approximately a mean displacement due to coal consumption, and avoids the necessity for allowance due to reduction of speed when making the turns. The following are the observed data on the first three runs:

	Mean pressure in steam pipe.	Air pressure.	Mean revolutions per minute.	Observed time.	Speed.	First means.	Second means.
	Pounds.	*Inches.*		*M. S.*	*Knots.*	*Knots.*	*Knots.*
First mile.....	153	1½	394.12	2 11	27.481	29.392	29.445
Second mile.....	154	1 5/16	403.3	1 55	31.304	29.498	
Third mile	152	1¼	394.8	2 10	27.692		

The 2¼ hours' run followed, and for this the total number of revolutions was 54,674, or 405 per minute. The following are the figures for the second series of runs:

	Mean pressure in steam pipe.	Air pressure.	Mean revolutions per minute.	Observed time.	Speed.	First means.	Second means.
	Pounds.	*Inches.*		*M. S.*	*Knots.*	*Knots.*	*Knots.*
First mile.....	156	1⅜	411	1 53½	31 718	30.032	30.102
Second mile.....	159	1⅜	412.2	2 7	28 346		
Third mile.....	162	1⅜	410 1	1 52½	32.000	30.173	

The mean speed on the six runs was therefore 29.773 knots. As the first mean of the revolutions per minute of the six mile runs was 405.15, the true mean speed of the vessel for the three hours was 29.762 knots; the coal burned during the three hours was 10 tons 7 cwt., with an average air pressure of 1.34 inches.

It will be seen, therefore, that the palm for the swiftest vessel in the world has once more reverted to the Poplar yard, and the British navy once more loses the supremacy in speed which it has held for some short time past. The maximum power exerted on Friday last did not reach 4,000, the mean during the trials being 3,700. Exactly what it was we are not aware, but taking a line through the spots obtained by progressive runs on the preliminary trial, it could not have exceeded 4,000. As a matter of fact, the highest speed is largely due to the precise attention paid to every detail, in order to insure lightness and efficiency.

A few examples may be given of the way in which the construction has been lightened. In the first place, nickel steel has been used for the hull. This in itself allowed a reduction in the scantling to be made, the material being stiffer and stronger than ordinary mild steel, and having high ductility. At the same time it is more expensive at first cost, and certainly more costly to work, so that it is not likely to be used for some time in vessels for the British navy. In the arrangement of the forced draft fan a saving in weight was effected by a very simple alteration. With the double stokehold necessary with water tube boilers the fan cannot, naturally, be mounted on the bulkhead, and it is there-

fore necessary to place it in the deck. In former destroyers, engine and fan were both attached to the deck, which had therefore to be greatly strengthened, thus entailing additional weight. In the *Sokol*, the engine is placed on the stokehold floor, and works the horizontal fan above by means of a vertical shaft. A canvas screen is provided to protect the engine from dust, and has proved quite effective. In the fittings and hull construction, again, aluminum has been extensively used in places where strength is not of first importance. Thus the side scuttles, bunker lids and rings, ejectors, cylinder casings, &c., are of that metal. It need hardly be said that this also adds to the cost of construction. The steam steering engine is of a new design, and has been made by the firm. The gear is of novel arrangement, and by its adoption, together with the improvement in the engine, a considerable saving in weight has been effected. In the main engines there are several points noticeable. The link motion has been altered, and the system of balancing has been modified from Mr. Yarrow's original design in some matters of detail, so as here again to secure additional lightness. Throughout the engines a considerable saving of weight has been effected by using the stronger and more costly bronzes, which have enabled less material to be worked in without sacrificing strength.

In this vessel the system of shutting off the boiler from the stokehold by means of a cross diaphragm plate in front of the boilers, which Messrs. Yarrow have adopted from the first, is introduced. With this arrangement, if the boilers are damaged in any way, say from the fire of machine guns during action, steam will not flow to the stokehold where the men are, but will pass up to the funnel. The arrangement, though not new, is worth noting here, as a very striking object lesson has been given during the recent war in South America. A number of men were killed during action by the escape of steam to the stokehold through damage done to the boilers. Had the arrangement adopted by Messrs. Yarrow been fitted to this vessel, although the boilers would equally have been put out of action, the men would not have been scalded to death or suffocated by steam.

An inspection of the boilers when the machinery was opened out indicated that they had been subjected to no excessive test. In the inner rows of tubes, which were quite easily examined, and which are subjected to the severest ordeal, there was no sign of leakage in any part, the tube ends, where they are expanded into the receiver above or the tube plates below, being perfectly tight and sound, and this may be said of the whole of the tubes, as there was no sign of leakage throughout. The tubes themselves did not present the symmetrical appearance of a new boiler, being bent a little out of straight. That, however, is the characteristic of all straight tube boilers of this description, and naturally in itself does not affect the steaming properties of the boiler. The large fire-grate area of these boilers leads to ease in working; indeed, the difference between running a trial with water tube boilers and with the old locomotive marine type, is only equaled by the difference in the appearance of the two types of boiler after the run.

In the case of the *Sokol*, although she had been steaming about 30 knots for three hours, the paint on the four chimneys was as fresh as when put on. The uniformity of the speed throughout the trial is worthy of attention. The run on the 2¼ hours exactly corresponds in number of revolutions per minute to the mean of runs made before and after the 2¼ hours. It is often assumed that it is impossible to work water tube boilers without considerable variations in steam pressure, owing to the small amount of water they contain. The regularity in the speed of revolutions could hardly have been obtained had not the pressure been constant. It is also satisfactory to notice the small increase of air pressure that occurred during the trial, as this indicates that there was no practical falling off in the efficiency of the boilers, owing to accumulation of cinders between the tubes or to the choking of the grates.

On Saturday, October 2, special trials at less than full power were made on the Maplin mile. Advantage was taken of the occasion to show the vessel to a number of foreign Government officials and others, but no representative of the British Admiralty

was present. In addition to the crew, there were about 100 persons on board. The chief features of the trials were two half-hour runs. The first was made with open stokeholds. With 274 revolutions the indicated horse power was 1,050, and the speed 20.5 knots. The height of the top of the smoke pipe above the grate bars is 20 feet. On the second half-hour's run hatches were closed, and a plenum of ½ inch was maintained in the stokeholds. This is known in the British navy as "natural draft," while some people call it "assisted draft." The revolutions now went up to 359 per minute, the indicated horse power to 2,650, and the speed to 26.74 knots. It will be seen, therefore, that in the first case it required, roughly, 51 horse power to be developed for each knot steamed; and, in the second case, nearly 100 horse power; while at the full speed attained (taking it to be 30 knots with 4,000 indicated horse power) about 133 indicated horse power per knot were required.

Admiral Oushakoff.—This coast defence vessel has already been described on page 210 of Vol. VI, and on page 175 of this year's February number. The following particulars of her steam trial, on October 3, in the Baltic, are from "Engineering," London:

She is the first vessel of a class which is specially designed for coast defence, but which can also be utilized for foreign service under certain conditions. She has been constructed at the well-known Baltic works at St. Petersburg, where her keel was laid June 16, 1892, and the vessel launched October 27, 1893.

The conditions of the trials were to maintain at least 5,000 indicated horse power for twelve consecutive hours with natural draft and open stokeholds. The results obtained were highly satisfactory, the mean horse power for twelve hours being 5,764.8 and mean speed 15 knots. All machinery worked with the greatest possible smoothness, a steady steam pressure being easily maintained; the trial was remarkable for its uniformity.

The trial was made under the direction of Mr. John Sampson, of Messrs. Maudslay, Sons and Field, engineers and constructors of the machinery, and was witnessed by representatives of the Russian government.

General Admiral Apraxine.—This is another of the coast

defence vessels, practically the same as the *Oushakoff*, mentioned above. The general dimensions are:

Length, feet	277.2
Beam, feet	52
Draught, mean, feet	17
Displacement, tons	4.061
I.H.P., forced draft, about	4.932
Speed, knots, natural draft	14
forced draft	16
Coal supply, normal, tons, about	210
greatest, tons, about	384

The side armor is 177 feet long, 6.56 feet high and tapering in thickness from 10 inches in the middle to 8.86 inches forward and 7.87 inches aft, the ends being connected by athwartship armored bulkheads, 7.87 inches thick forward and 5.9 inches thick aft. The armor for the two turrets, in each of which are two 9-inch guns, is 7.87 inches thick. The amored deck is 3 inches thick on the inclined sides and 2.64 inches on the flat part.

Besides the four 9-inch guns, there are four 5.9-inch Canet rapid fire guns in redoubts; six 1.85-inch and eight 1.46-inch rapid fire guns, and four 1.46-inch rapid fire guns in the fighting tops. There are four torpedo tubes, one forward, one aft and one on each broadside.

The engines are twin-screw, vertical, triple expansion, in separate compartments, and there are eight boilers.

Samoyede.—This armored transport, built and fitted for hydrographic service, has already been described on page 607 of the last number of the JOURNAL. The official trials took place on August 20, with the following results: The contract required a six hours' continuous run. Before starting on this, nine runs were made over the measured mile at the Maplins, the mean speed attained being 12.5 knots, about one knot in excess of the contract speed. The mean draught of vessel was 11 feet; revolutions of engines, 142 per minute; vacuum, 28 inches; steam pressure in boilers, 160 pounds per square inch; I.H.P., 1,495. The six hours' continuous running was then undertaken, part of the time being over the measured mile. The mean speed for the whole trial, which lasted nearly seven hours, was 12.6 knots.

SPAIN.

Almirante Oquendo.—The following description is from "Engineering," London:

The third of three cruisers built at the Astilleros del Nervion, at Bilbao, has completed her speed trials. The trials took place between Bilbao and San Sebastian on Monday, August 26, and were in every way satisfactory. Starting from Bilbao at 7 A. M., the cruiser was on the measured mile in two hours. Four runs were made, after which a six hours' run was completed, whereupon the vessel again ran the mile four times, the mean revolutions determining the speed on the six hours' run. This was under natural draft. The mean revolutions were 105, the power about 9,000 indicated horse power, and the speed 18.49 knots. Subsequently a run for slightly under an hour was made with forced draft to ascertain that everything worked well. This was regarded as sufficient in view of the fact that the machinery was identically the same as in the two preceding cruisers, *Infanta Maria Teresa* and *Vizcaya*, the former of which had been most exhaustively tried. (These trials and the complete description of the *Maria Teresa* were published on pages 621–631, and the results of the trials of the *Vizcaya* on page 810 of Vol. VI of the JOURNAL.) Everything worked well with the engines running at 117 revolutions. A single-screw trial was then undertaken, for about half an hour. The number of revolutions was 85, and the speed 12¼ knots. In the construction of this vessel much Spanish skill and labor has been utilized under the direction of Mr. James McKechnie, the engineering manager of the works.

UNITED STATES OF COLOMBIA.

Gunboat.—The following particulars of the gunboat built by Mr. Hugh Ramsey, of Perth Amboy, N. J., are taken from the "Marine Record":

The contract calls for a side wheel gun boat, to be ready for transportation on January 1, 1896.

It is stipulated in the contract that the gunboat shall be completed in four months and shipped to the United States of Colombia in sections, the reconstruction and fitting out to be done by

that government. Despatch and torpedo boats have been built in sections, both here and abroad, and shipped away, but these boats so constructed have been small, and the transportation in sections of the new gunboat, which is to be 140 feet long, will, according to Mr. Ramsey, be an unusual one. The gunboat will be put together at the yard with screw bolts, which will permit of breaking her up without injury to her frame or plates.

The new vessel will be a side wheel steel gunboat to be used for river service. She will have a speed of 15 knots and a draught of only 3 feet 3 inches. Her dimensions will be: Length over all, 140 feet; beam, over guards, 35 feet, at the water line, 19 feet; and depth of hold, 7 feet. She will have a military mast, on which will be mounted a machine gun and steel covered conning tower. On the latter will be a powerful search light.

The engine and boiler rooms will be protected with ¼-inch bullet proof nickel steel. The deck house will have instead of windows, steel sliding panels, from behind which the crew can fire without being exposed. The hull will be divided into ten water tight compartments, the saloon and staterooms being aft. She will have inclined triple expansion engines, with cylinders 12¾, 20½ and 31¾ inches in diameter, the stroke being 39 inches. The feathering paddle wheels will be 9 feet in diameter and 3 feet wide. Her armament will consist of three rapid firing machine guns, one mounted forward, one aft and one on the military mast. She will burn wood, her fuel capacity being small, as it is expected that she will always be able to obtain fuel all along the rivers.

When completed the gunboat will cost in the neighborhood of $125,000.

MERCHANT STEAMERS.

St. Louis.—The official trial, to determine whether this vessel fulfilled the requirements laid down in the Mail Subsidy Act for vessels of 20 knots' speed, took place in the English Channel on August 20. She ran 104 nautical miles, 52 with and 52 against the tide, the resulting mean speed being 22.3 knots.

Our attention has been called to an error in the description of the steering engine of the *St. Louis* on page 617, first paragraph, of the last number of the JOURNAL. The correction is as follows:

"The steering engine of the *St. Louis* is not of the Brown arrangement, but is of the same style as is used on the U. S. Naval cruisers and battleships. It is operated by the Brown telemotor.

"The steering engine of the *St. Paul* is of the Brown type throughout, and was constructed by the Messrs. Williamson Bros., of Philadelphia, from drawings furnished by the Messrs. Brown Bros."

St. Paul.—Sister ship to the American liner *St. Louis*, has also had her official trial of four hours' duration, under the terms of the Mail Subsidy Act. This trial took place on October 4, over a measured course of 41.96 nautical miles, between Cape Ann, Massachusetts, and Cape Porpoise, Maine. The vessel's bottom was foul. The mean speed attained was 20.5 knots.

On October 9, she left New York on her maiden voyage to Southampton, England, the run being made in 7 days 12 hours and 20 minutes, from the Sandy Hook Light Ship to the Needles. The greatest daily run was 439 miles.

Carinthia and *Sylvania.*—The following description of the vessels and the trials have been taken from "Engineering," London:

These new Cunard steamers have excited great interest by reason principally of the high efficiency of the boilers and engines,

and were referred to, on this account, in the course of a debate in Parliament a month or two ago, when the question of the relative merits of the water tube and multitubular boilers was under consideration. They are the first of a new type added to the Cunard fleet. The company have hitherto been satisfied with their large share in the passenger traffic, and such freight as is carried by the mail steamers; but owing to the great advances in speed, the cargo capacity has steadily decreased, for the class of freight which can be profitably carried at 20 and 21½ knots speed is limited, and there is little need to add thus to the displacement of high speed vessels. Again, the live cattle traffic has been steadily increasing, and the company, in deciding to build cargo steamers of great deadweight carrying capacity, provided also for a large cargo of cattle on the main deck. Thus 6,500 tons of cargo may be carried, and 420 head of cattle; and judging from the experience of the first voyages of the steamer, there is every prospect of the new class being increased. The vessels again, are, the first constructed by the London and Glasgow Engineering and Iron Ship Building Company, Limited, for the Cunard Company, who had probably the greater confidence in placing the order in view of their experience with the general manager of the company, Mr. J. W. Shepherd, some time manager at Fairfield, where he had charge of the building of those very successful steamers, the *Umbria* and *Etruria*, and many large steamers for other companies. It was a small matter, therefore, that the London and Glasgow Company had not formerly undertaken the building of such large steamers. The dimensions of the steamers are as follows:

Length, feet	460
Breadth, feet	49
Depth to shelter deck, feet and inches	42–6
Cargo capacity, deadweight, tons	7,500
Draught, fully loaded, feet	27
Displacement, fully loaded, tons	12,160
Freeboard from upper deck, fully loaded, feet and inches	8–4
Gross tonnage, about, tons	5,600

The ventilation of the cattle spaces and holds is an important feature in the vessel, Utley's patent cowl and combination vents

being provided throughout the ship. In addition to this, portions of the shelter deck can be hinged up in good weather and form uptakes.

There are six holds, with large hatches, and these are served by seven large steam winches, each having double derricks, specially constructed for loading cargo from barges alongside. These are supplied by Messrs. Clarke, Chapman and Co., as are also the steam windlass and capstan forward, and the steam warping capstan aft. Messrs. Harrison's steam steering gear is fitted in the after end of the engine casing, and in communication with the engine room, having a direct lead to the large circular head in the wheelhouse on the shelter deck aft, where a powerful screw gear, as well as an auxiliary gear, is fitted up for working the ship by hand if required.

The captain's and deck officers' and spare state rooms, as well as the saloon, are situated on the shelter deck at the fore end of the engine and boiler space, and each officer has a large and comfortable apartment for himself, heated by steam and lighted by electric light. The engineers have the same accommodation as the other officers, and their rooms are built round the engine casing, the entrances all being from the engine platform. There is one feature about the vessel which will commend itself to those who have the working of it, viz., there are no obstructions or ladder ways to get over in order to get from one end of the ship to the other, a free passage being left all fore-and-aft at the sides of the ship. There are four steel pole masts, fitted with fore-and-aft canvas for steadying purposes. The twin screw propelling engines are very compact, the cylinders being 22½ inches, 36½ inches and 60 inches in diameter, by 48 inches stroke.

Each cylinder is fitted with a separate liner and steam jacketed. The high pressure and intermediate pressure pistons are fitted with cast-iron Ramsbottom rings, the low pressure pistons having Lockwood's patent packing rings and springs. The piston rods are of mild ingot steel, 6 inches in diameter, with separate crossheads. The connecting rods, which are 5¾ inches in diameter, tapering to 7 inches, are of iron, with double gun metal bearings

on the top ends, and brass bushes lined with white metal. Each set of engines has one air pump, diameter 22 inches, stroke 24 inches, fitted with Kinghorn's disc valves; two feed pumps, 3½ inches in diameter; two bilge pumps, 4 inches in diameter; and one sanitary pump—all single acting and worked by levers off the intermediate pressure engine. The feed pumps are arranged to discharge to the feed water heater, or direct to the boilers.

The condensers are short, the high pressure cylinder being supported at the back by a duplicate of the front column. The condensing surface in each is 2,750 square feet; the tubes are tinned outside and in, and packed with screwed ferrules and linen tape packing. The exhaust from the low pressure cylinder enters the condenser through the after column. The circulating pumps are two in number, one for each set of engines, made by Drysdale and Co., Glasgow. The diameter of suction and delivery pipes is 10 inches. The discharge of the centrifugal pumps is bolted direct on to the condenser end, and the pump and engine are supported on brackets attached to the condenser.

All the shafting was supplied by Vickers & Co., of Sheffield. The crankshaft is 12½ inches in diameter. The crankpins are 12¾ inches in diameter. The thrust blocks are of the ordinary horseshoe type, with water circulation through the shoes. There are eight collars on each shaft 2 inches thick. The length of thrust shaft is 11 feet 1 inch by 12½ inches in diameter, and 21¼ inches in diameter over thrust rings. The intermediate shafting is 12 inches in diameter, and the propeller lengths are 12½ inches in diameter. The propellers are 16 feet in diameter, each having three blades, with 60 square feet of surface, cast by the Manganese Bronze Company. The bosses are cast iron.

The outfit of auxiliary engines consists of one Cameron's quadruple-acting water ballast pump, capable of discharging 300 tons per hour; two of Carruther's duplex pumps, having brass water ends, for bilge and general service, and together with the ballast pump, arranged to discharge into water space of main condenser; one Carruther's duplex pump for supplying fresh water to cattle from four reserve tanks under engines; two of Quiggin's evaporators with steam feed pump, and one fresh water distiller,

together having a capacity of 50 tons per 24 hours. The evaporators are also fitted to work as condensers for the winches and auxiliaries generally, all of which can also exhaust into the main condenser. The circulating water for the winch condenser is supplied by either of the water ballast pumps and either of the duplex service pumps.

The boilers are of special interest. They are worked under Howden's system of forced draft. The fan is 8 feet in diameter, and is driven by one of Chandler's engines. Two engines are provided, one for emergency duty. Two boilers were sufficient for the full power, 2,725 indicated horse power. These boilers are 20 feet 3 inches long and 15 feet in diameter. They have each six furnaces 3 feet 7½ inches in internal diameter, being fitted with Fox's flues. The following details of each of the two boilers will be of interest:

Number of plain tubes	542
stay tubes	274
Total number of tubes	816
Heating surface of tubes, square feet	4,204
furnaces, square feet	281
fire boxes, square feet	230
inner tube plate, square feet	90
Total heating surface, square feet	4,805
Steam space, cubic feet	800
Evaporating surface, square feet	260
Weight of water, tons	41.47
Grate surface on 5-foot bars, square feet	110
Ratio of grate to heating surface	1 to 43.6
Probable consumption of coal per square foot of grate per hour, pounds	28
Safety valves, three combined, diameter, each, inches	3¾
Limiting tensile strength of steel shell plate, Board of Trade, tons	28 to 32
Limiting tensile strength of steel shell plate, Lloyd's, tons	28 to 32

There is also a large auxiliary boiler for winches, electric light, &c. There is one of Weir's feed heaters with steam supply from each set of engines. Two pairs of Weir's feed pumps are fitted, having brass water ends and distribution chests, and arranged to draw from the sea, evaporator, tanks, condenser, hot well and feed heater, and discharge to the main and auxiliary boilers direct, and through or past Harris's feed water filter to the heater. Steam

fire-extinguishing pipes are fitted to all the compartments of the holds and bunkers. Higginson's steam ash hoists are fitted in each stokehold.

The *Sylvania* was tried on the Firth of Clyde, running first six times over the mile and twice between the Cloch and Cumbrae. It was a coarse morning, but the speed exceeded the conditions, as the following results show:

RESULTS OF TRIALS OF S. S. *SYLVANIA*.

Draught, forward, feet and inches	15–9
aft, feet and inches	19–6
mean, feet and inches	17–7½
Displacement, tons	7,420

SIX RUNS ON THE MEASURED MILE.

	Boiler pressure.		Revolutions.		Power.		Total power.	Speed.
	Port.	Starboard.	Port.	Starboard.	Port.	Starboard.		
	Pounds.	*Pounds.*						*Knots.*
1st	175	172	91.4	93.4	2,269	2,257	4,527	15.32
2d	175	180	93.8	95.0	2,741	2,749	5,490	15.25
3d	175	180	93.9	95.0	2,798	2,740	5,539	15.65
4th	175	180	92.5	94.5	2,766	2,792	5,558	15.25
5th	175	180	94.2	95.0	2,777	2,778	5,556	15.45
6th	175	180	92.0	94.0	2,715	2,746	5,462	15.00

MEANS ON MEASURED MILE.

	Port.	*Starboard.*
High pressure cylinder	757.30	815.0
Intermediate pressure cylinder	840.18	957.7
Low pressure cylinder	1,080.87	904.6
Total	2,678.35	2,677.3
Total I.H.P., both engines	5,355.65	
Mean speed, knots	15.32	
Air pressure in fan discharge, inches	3½	
ashpit, inches	1⅛	
furnace, inch	1	

On the two runs between the lights the mean boiler pressure was 178 pounds, the vacuum, as in the six runs on the measured

mile, being 28 inches. The revolutions were, for the port 93 and the starboard 95, and the mean powers were as follows:

	Port.	*Starboard.*
High pressure cylinder	772.3	815.1
Intermediate pressure cylinder	854.1	1,010.8
Low pressure cylinder	1,100.9	899.6
Total	2,727.3	2,725.5
Total indicated horse power, both engines	5,452.8	
Speed, knots	15.52	
Mean slip of port screw, per cent	8.69	
starboard, per cent	6.407	

As to the results on the measured mile, it should be stated that on the first run both engines were pulled up two or three times by Aspinall's governor, which had been left in gear. On the runs between the lights a more direct course was steered, which accounts in large measure for the difference in speed. The power developed between the lights was equal to 24.8 indicated horse power per square foot of grate surface, and 1 indicated horse power per 1.72 square feet of heating surface. As to coal consumption, no attempt was made to measure it, as there was no time, the vessel being required on her berth. It was estimated at 86 tons per 24 hours.

The *Carinthia* was not tried over the measured mile or between the lights, but was run a distance of fully 90 miles, viz., round Ailsa Craig and back to the Tail of the Bank. She did the distance in less than six hours, equal to 15¼ knots. Both vessels have been on their station for some time, and are working satisfactorily.

The hull is entirely built of Siemens-Martin steel, the rivets being also of this metal. The shell plates are generally about 22 feet long, lap jointed and treble riveted. The orlop, lower, main and upper decks are of steel. The shelter deck is partially plated and then sheathed with pine.

As the vessels are propelled by twin screws, the framing of the after end is carried out to meet the stern tubes, and ends in a massive steel casting on each side, which is shaped into the form of the vessel. There are nine water tight bulkheads extending to the upper deck, and these are fitted with water tight doors on each side in 'tween decks only, to expedite the working of cattle

and cargo. Besides the double bottom, which is fitted for water ballast, there are four large deep tanks for trimming purposes, one aft, one forward, and one at each end of the engine and boiler space, these being subdivided by fore-and-aft water tight bulkheads. There are in all twenty-four compartments for water ballast, and part of the double bottom under the engines may be utilized for carrying reserve fresh water for cattle or boiler use. The bulkheads are so arranged that any two compartments, and in some cases three, may be flooded, and still the vessel will keep afloat. Although built to Lloyd's highest class, 100 A 1 three-deck, the vessels have special extra strengthening at the bilge and topsides, and, in addition to the usual Board of Trade survey, are fitted to pass the American survey, having fusible plugs in the boilers, Downton fire pump, and steam pipes for extinguishing fire in every compartment.

All the holds, 'tween decks, engine and boiler spaces, cabins, and the vessel throughout are lighted with electricity on the double wire system, the current being generated by two compound wound self-regulating dynamos, situated in the engine room, and at each of the seven hatches there is a cluster of sixteen lamps of 16-candle power. This work has been carried out by Messrs. William Harvie and Co., Limited.

Accommodation is provided for 420 head of cattle on the upper deck.

Sumatra.—This single-screw steamer of the P. & O. Co. was partially described on page 626 of the last number of the JOURNAL. Since then, the following particulars of the machinery have become available.

The main condenser is cylindrical, built up of wrought-steel plates and has cast-iron ends, the cooling surface being 4,385 square feet. The air pump is worked from the L.P. engine, and is large enough to enable the condenser to be worked as a jet condenser in an emergency. A bilge pump and a sanitary pump are alongside of the air pump and worked by the same cross-head. The circulating pump is independent and centrifugal, 12½ inches in diameter.

The crank shaft is of Vicker's steel, its bearings being lined

with Parson's white metal. All main pistons have Ramsbottom rings. The H.P. piston valve is fitted with MacLaine's patent rings. The reversing gear is designed by the builders, and reverses the engine, from full ahead to full astern, in ten seconds. There is a Morison evaporator, of 20 tons daily capacity, a Morison feed water heater, and a Caird & Rayner distilling apparatus capable of supplying 2,000 gallons of drinking water per day. There are two automatically controlled Weir feed pumps, one Weir duplex pump for general engine room service and a ballast pump which can pump out the whole water ballast, nearly 800 tons, in five hours.

The thrust bearing has a thrust surface of 1,750 square inches.

The propeller is four bladed, with manganese bronze blades on a cast iron boss. Zinc slabs are fitted to the forward side of the rudder post to prevent galvanic action.

There are two main double ended, cylindrical boilers, 13 feet 8 inches in diameter and 18 feet 6 inches long, working at 160 pounds pressure and fitted with Howden's forced draft system. The combined grate surface is 154 and the heating surface 6,720 square feet. Morison's suspension furnaces are used. There is a large donkey boiler which also has Morison's furnaces and works at 160 pounds pressure.

There are two independent sets of Siemens Bros'. dynamos, each set being capable of lighting the whole vessel.

Ventilating arrangements are provided, the engine and fire rooms being remarkably cool.

The trials of this vessel took place in the Firth, on August 20, but no data are published.

Pennsylvania.—This steamer of the Hamburg-American S. S. Co., now building by Messrs. Harland & Wolff, Belfast, Ireland, will be the largest steamer afloat. The contractors agreed to build the vessel in ten months, while two German bidders wanted fifteen months. The principal dimensions are as follows:

Length on load water line, feet	560
Beam, feet	62
Depth, feet	42
Deadweight carrying capacity, tons	13,000
Displacement, tons	20,000

The engines will be twin-screw triple expansion. There will be one smoke pipe and four pole masts. There will be accommodations for 200 cabin and 1,500 steerage passengers. Besides carrying "fast freight", arrangements have been made for cattle, and ample refrigerating apparatus provided for perishable freight.

North German Lloyd S. S. Co.—The new steamer of this company, for which the contract has been given to Mr. Schichau, Elbing, Germany, is guaranteed to make 22 knots on trial and 21 knots in regular service.

Kherson.—This auxiliary cruiser for the Russian Volunteer Fleet, a general description of which was given on page 618 of the last number, was launched from the yard of Messrs. Hawthorn, Leslie & Co., Hebburn-on-Tyne, on October 19.

She is arranged to carry about 1,500 soldiers or emigrants and about 100 other passengers. There are 24 Belleville boilers, particulars of which will be found in the article on the test of two of these boilers under the head of "Notes," page 791.

Scottish Hero.—This steamer was built by Messrs. William Doxford & Sons, Sunderland, England. She is one of the "turret" type of steamships described on page 620 of the last number of the JOURNAL, and has joggled plating throughout. The principal dimensions are: Length between perpendiculars, 297 feet; breadth, moulded, 40 feet; depth, moulded, 24 feet 1 inch. The gross register tonnage is 2,201 tons and the deadweight capacity, 3,800 tons.

The engines are of the quadruple expansion type, with cylinders 19½, 27½, 39 and 55 inches in diameter, the stroke being 42 inches. The three boilers are of the Babcock & Wilcox water tube type, the two main boilers containing 4,500 and the donkey boiler 990 square feet of heating surface. The main boilers are fifteen, the donkey boiler eight sections wide. The height and length are the same. The main boilers have 4-inch tubes in the bottom rows, the others being 1⅞-inches in diameter. The donkey boiler has 4-inch tubes entirely. On trial, the machinery easily developed 1,500 horse power, the resulting speed for four hours on the measured mile with the full deadweight on board being 10.2 knots. The engines and boilers worked satisfactorily.

Chesapeake.—This tank steamer, described on page 624 of the last number of the JOURNAL, had her trials in August. The mean speed attained on August 15 on the progressive trials was a little less than 12¼ knots, the displacement being 9,000 tons. On August 17, for the six hours' run and with the same displacement, the mean speed was 12 knots, or ¼ knot over the contract requirement. The *Chesapeake* was the largest tank steamer afloat until the launch of the *Pectan*, described below.

Pectan.—This steel tank steamer, which had her trials in the latter part of September, was built for the bulk petroleum trade to the East through the Suez canal, by the Central Marine Engine Works of Messrs. William Gray & Co., West Hartlepool. She is the largest bulk oil steamer afloat, takes Lloyd's highest class, and her dimensions are: Length over all, 388 feet; breadth, extreme, 48 feet; depth, 31 feet 6 inches, with full poop, bridge and forecastle. The engine and boiler rooms are in the after part of the vessel, and underneath them there is a double bottom for water ballast. The forward and after peaks and deep tank in the fore hold are also fitted for water ballast for trimming purposes. Forward of the boiler room there are 11 strong transverse bulkheads, and also a very strong fore-and-aft bulkhead from the keel to the main deck. Altogether there are 15 separate oil tanks, separated from the boiler room and bunkers aft and from the cargo hold forward by large cofferdams, which are carried to the upper deck in each case. Expansion trunks are carried up from each oil compartment to allow the oil to rise and fall as the temperature varies. A complete installation of pumps, fans and electric light for the oil compartments has been fitted. Triple expansion engines have been fitted, the cylinders being 27½ inches, 43½ inches and 73 inches in diameter, with a 48-inch stroke. There is a Mudd's patent evaporator. There are three extra large single-ended boilers working at a pressure of 160 pounds per square inch, placed with their backs towards the cofferdam, removing the heat arising from the stokehold a considerable distance from the bulkheads. The speed on trial shown by the log was 11 knots.

Telena.—A sister ship to the *Pectan*, and built at the same works, was launched on October 19.

YACHTS.

Alcedo.—The following description is taken from the "American Shipbuilder," New York, September 5:

This flushed-deck steam yacht of composite construction, was built by George Lawley & Son, City Point, South Boston, Mass. The general dimensions are as follows; length, 124 feet over all, 102 feet at load water line; 16 feet 2 inches beam; 6 feet 6 inches draught. The hull is subdivided into five compartments by four steel water tight bulkheads. The scantlings conform in all particulars to the requirements of the U. S. Standard Steamship Owners', Builders' and Underwriters' Association. The hull is stiffened by a system of steel straps worked diagonally over the frames and deck frames. The planking of the hull is of Georgia pine 2⅜ inches thick, fastened to the frame with nut and screw bolts; all fastening to a height of 2 feet above the water line is of bronze. The deck is of clear white pine; the main rail is of teak; the deck house, skylights and hatches are of mahogany; over the engine and boiler space is a low steel house 10 inches high. The engines are forward of the boiler.

The cabin accommodations are extremely commodious and convenient. The dining room is forward in the deck house, finished in mahogany throughout. It is 18 feet long by 8 feet 6 inches wide, connected with the galley and pantry below by a dumb waiter. The entire deck house is used as a dining room and deck saloon, the steering gear being on the bridge deck overhead. Directly aft of the machinery space and separated from it by a steel water tight bulkhead, and protected from the heat of the boiler and the noise of the fire room by an across coal bunker, is the owner's stateroom. Aft of this is the main saloon, 13 feet 6 inches long. Aft of the main cabin is the hallway from which leads the companion way to the main deck. Leading from the hallway, there is on the port side a single stateroom, and on the

starboard side, a toilet room. Aft of the hallway is a double stateroom.

Especial attention has been given to the sanitary arrangements of the yacht; the bath tub and set bowls in the cabin quarters are trapped and piped to a tight waste tank in the after hold and which is vented overboard. The waste tank is emptied by a steam syphon, located in the engine room. The ventilating arrangements are very ample, each room having a direct skylight ventilation. For the bilge ventilation there is an 8-inch exhaust ventilator located on deck and leading down into the after hold, which will continually draw air from the same. Forward of the machinery space and directly below the dining room comes the galley, 10 feet long, and the full width of the yacht. On the starboard side is the pantry from which leads the dumb waiter to the dining room above, with butler's sink and racks for dishes, etc. The galley and pantry are ventilated by a high skylight on either side of the deck house in addition to the port lights in the side of the hull. Forward of this are the quarters for officers and crew. Forward of the collision bulkhead are the chain lockers, also the engines to the steam capstan on deck. The triple expansion engine with cylinders of $9\frac{1}{2}$, 15 and $24\frac{1}{2}$ inches diameter and a stroke of 13 inches, was built by the Fore River Engine Co., of Weymouth, Mass. Steam is furnished by a double fire box, water tube boiler of the Almy type, licensed to carry a pressure of 250 pounds to the square inch. The circuculating, air, feed and bilge pumps are all independent and are arranged to exhaust into either the low pressure receiver or the condenser.

The condenser is 6 feet long, 36 inches diameter, copper shell, brass heads and tubes, and contains 650 feet of cooling surface. The circulator is of the centrifugal type with direct connected engine, built on the condenser head, and runs at at average speed of 300 revolutions. The crank shaft is built up of open-hearth machinery steel; the bearings are lined with Fore River white metal. The crossheads are of bronze and the pistons of cast steel, with spring rings as lightly constructed as is consistent with strength. The piston valves, which are of cast iron, are

actuated by a side crank shaft driven from the main shaft by steel and rawhide gears. The reversing is accomplished by a spiral sleeve, working on a spiral on side shaft. The spirals and sleeves are cut from the solid steel. The propeller is four-bladed, 5 feet in diameter and 7 feet pitch. The ordinary number of revolutions of engine, with a steam pressure of 200 pounds per square inch, is 320 per minute. The three main compartments of the yacht are piped independently to the bilge pump and syphon; the machinery compartment is also connected with the circulating pump. The coal bunkers have a capacity of 18 tons. The yacht is lighted throughout by electricity by a direct-connected multipolar dynamo, and there is a small auxiliary storage battery for use when the dynamo is not running. The yacht will carry three boats, a gig 18 feet long, a cutter 16 feet long, and a dinghey 15 feet long. The davits for the gig have been made extra heavy to carry a naphtha launch, should it be desired to do so.

Arcturus.—This auxiliary steam yacht was launched on October 18 from the works of the builders, Messrs. Ramage & Ferguson, Leith, Scotland. Her tonnage is 473, yacht measurement.

She was built for Mr. R. Stuyvesant, of New York. The yacht has three masts and a large spread of canvas, as the owner intends to use her for long foreign cruises, and the propeller is of the Bevis feathering type. The principal dimensions are: Length on load water line, 135 feet: length over all, 169 feet; breadth, 27 feet; depth, moulded, 17 feet 5 inches. There are two large deck houses, the one forward containing pilot and chart house, also smoking room, and the after one forming a handsome dining room. The machinery consists of a set of triple expansion engines made by the builders, having cylinders 13, 21 and 34 inches in diameter by 24 inches stroke. Steam is supplied by two Almy water tube boilers, made at Providence, R. I., this being the first British built yacht fitted with these American boilers. Steam steering gear, winches and windlass are fitted. The yacht has a powerful search light and electric lighting throughout.